VOLUME 18, NO. 4
APRIL 1986

THE SHOCK AND VIBRATION DIGEST

A PUBLICATION OF
THE SHOCK AND VIBRATION
INFORMATION CENTER
NAVAL RESEARCH LABORATORY
WASHINGTON, D.C.

OFFICE OF
THE UNDER
SECRETARY
OF DEFENSE
FOR RESEARCH
AND
ENGINEERING

THE SHOCK AND VIBRATION DIGEST

Volume 18, No. 4
April 1986

The Shock and Vibration Digest is a monthly publication of the Shock and Vibration Information Center. The goal of the Digest is to provide efficient transfer of sound, shock, and vibration technology among researchers and practicing engineers. Subjective and objective analyses of the literature are provided along with news and editorial material. News items and articles to be considered for publication should be submitted to:

Dr. R.L. Eshleman
Vibration Institute
Suite 206, 101 West 55th Street
Clarendon Hills, Illinois 60514
(312) 654-2254

Copies of articles abstracted are not available from the Shock and Vibration Information Center (except for those generated by SVIC). Inquiries should be directed to library resources, authors, or the original publishers.

This periodical is for sale on subscription at an annual rate of $200.00. For foreign subscribers, there is an additional 25 percent charge for overseas delivery on both regular subscriptions and back issues. Subscriptions are accepted for the calendar year, beginning with the January issue. Back issues are available -- Volumes 11 through 16 -- for $40.00. Orders may be forwarded at any time to SVIC, Code 5804, Naval Research Laboratory, Washington, D.C. 20375-5000. The Secretary of the Navy has determined that this publication is necessary in the transaction of business required by law of the Department of the Navy. Funds for printing of this publication have been approved by the Navy Publications and Printing Policy Committee.

A publication of

THE SHOCK AND VIBRATION INFORMATION CENTER

Code 5804, Naval Research Laboratory
Washington, D.C. 20375-5000
(202) 767-2220

SVIC NOTES

MANY THANKS

On behalf of the Shock and Vibration Information Center, I wish to publicly thank our reviewers for taking their personal time, or time away from their busy schedules, to help us review the contributed papers and determine their suitability for publication in the 56th Shock and Vibration Bulletin. I am sure the authors also appreciate the efforts of the reviewers because their constructive suggestions have helped them to improve their manuscripts. Again, many thanks for your help.

Dr. Anthony Amos
Dr. Charles E. Anderson
Mr. Robert P. Andrews
Dr. Harry E. Auld
Mr. Carl F. Bagge
Mr. Monty Bai
Dr. Wilfred Baker, P.E.
Mr. Robert Bamford
Mr. Harold W. Bartel
Mr. Clark Beck
Dr. Alex Berman
Dr. Charles W. Bert
Mr. Donald Bettge, P.E.
Mr. Robert L. Bort
Mr. Arthur D. Carlson
Mr. Thomas G. Carne
Dr. C.I. Chang
Dr. J.C. Chen
Dr. Halsey B. Chenoweth
Dr. James Colton
Dr. Roy R. Craig
Mr. Herbert Curchack
Dr. Rocco Di Taranto
Dr. Ronald D. Dotson
Mr. Frank J. Fechek
Mr. William Flannelly
Mr. Ami Frydman
Dr. J.S. Fuh
Dr. Howard Gaberson
Mr. John Garba
Dr. Thomas L. Geers
Mr. Donald Graves
Dr. Jerry H. Griffin
Dr. Hans S. Gruenberger
Dr. John L. Gubser
Dr. Ronald Gularte
Dr. W.L. Hallauer, Jr.
Dr. John P. Henderson
Mr. Ralph Henrikson
Mr. David Hillyer
Dr. Donald Houser
Dr. Hanson Huang
Mr. Marvin P. Hughes
Dr. Michael Hundal
Dr. Rauof A. Ibrahim
Mr. Charles E. Joachim
Mr. James R. Johnson
Dr. David I. G. Jones
Mr. Robert Jones
Mr. Kenneth C. Kalbfleisch
Dr. Daniel Kana
Dr. William A. Keenan
Dr. David A. Keinholz
Dr. Arthur F. Kilcullen
Mr. D.W. Kintis
Mr. Matthew F. Kluesener, P.E.
Mrs. Mary E. Lacey
Mr. Ronald G. Lambert
Mr. Larry D. Mardis
Mr. James M. McAvoy
Mr. David McCalley
Dr. Ronald Merritt
Mr. Vincent Miller
Dr. Paul Mlakar
Mr. A.J. Molnar
Mr. Robert C. Murray
Dr. Hyla Napadensky
Dr. Frederick C. Nelson
Mr. David S. Nokes
Dr. Michael Pakstys
Mr. Richard S. Pappa
Mr. Gerald J. Petrak
Dr. Maynard Plamondon
Dr. Rodney F. Recht
Mr. Walter H. Reiman
Dr. R. Robinson
Mr. Paul L. Rosengren, Jr.
Dr. Fred Safford
Mr. Paul R. Schrantz
Dr. Paul N. Sonnenburg
Dr. Andres Soom
Dr. T.T. Soong
Dr. Frederick R. Tepper
Dr. Marc Trubert
Dr. Patrick L. Walter
Mr. William E. Wassman
Mr. Charles R. Welch
Mr. Peter Westine
Mr. Howard F. Wolfe
Mr. Fred H. Wolff
Mr. John Yagla

R.H.V.

EDITORS RATTLE SPACE

REPUBLICATION REVISITED

In past comments in this column, it has been my policy to examine factors and forces that affect the transfer of technology from developer to user. Republication is one of the more important issues involved in the technology transfer process. Republication of technical material in a condensed and distilled form makes retrieval unbelievably easy. Second and third publication of a paper or report with minor changes or additions tends to clutter the literature and make the process of retrieval much more difficult.

It is rare for researchers to publish condensed and integrated technology in monographs and books. Usually when books are written, they contain classical technology used in teaching courses. As a result we have hundreds of classroom oriented textbooks on mechanical vibrations but few monographs that deal with specialized technological areas. One of the greatest accomplishments of the late John Snowdon was to condense and distill his research work in the book, "Vibration and Shock in Damped Mechanical Systems." This book could be a model for many great researchers who have contributed vast amounts of excellent technology to the literature. Unfortunately their work is scattered throughout the printed literature over a number of years. It makes it difficult to retrieve a complete list of publications prior to 1969. Since that time the DIGEST has contained an author index for easy retrieval on an author basis.

The negative side of republication involves two or more publications that contain essentially the same technology. This tends to clutter the literature with references, makes it difficult to conduct a search, and strains the budgets of libraries. It has a detrimental effect on publishers because the sales volume becomes lesser as more publications come on the market. Thus the republication process has many negative effects.

The publication process could be vastly improved if every author would resist the pressure to publish just for the sake of publishing. The question should be asked whether this is material that either has not been published before or has not been published in the same organizational, condensed, or distilled form -- so it will be a genuine contribution to the literature. Publishers should use more technically oriented editorial advisers so that their material is less in volume and more relevant.

R.L.E.

A PRIMER OF RANDOM VIBRATION TECHNIQUES IN STRUCTURAL ENGINEERING

P.D. Spanos* and L.D. Lutes**

Abstract. A review of random vibration techniques for analyzing dynamic systems is presented from the perspective of applicability to structural engineering. Problems involving linear or nonlinear, elastic or inelastic structural models are addressed.

Over a period of years considerable interest has developed in random vibration analysis of dynamic systems used as models in structural engineering. The term random vibration analysis traditionally denotes the determination of response statistics of a deterministically known system exposed to a stochastic load. This interpretation of the term is adopted in the present review. Most of the current interest in structural engineering applications of random vibration analysis can be attributed to the fact that structural loads caused by earthquakes, sea waves, and winds can be adequately described on a stochastic basis.

The primary intent of this review is to introduce nonspecialists to a variety of existing methods for performing random vibration analyses within the context of structural engineering applications. A conscious goal of the authors is to present the different approaches and concepts in such a way as to emphasize similarities and differences. Even though details of analysis are not presented, the review may help the reader to choose an appropriate method for a given situation. The references are almost exclusively limited to standard books and review articles to maximize accessibility of the work to a varied audience. Mathematical rigor is somewhat relaxed for the same reason.

Mathematical models used in representing either structural members or entire structures can be classified as discrete or continuous. The advent of digital computational systems and the development of discretization techniques such as finite elements and boundary elements have resulted in domination by discrete systems of the mathematical models currently used in structural engineering applications. Thus, the present review *focuses on the applicability of random vibration* techniques to discrete dynamic models of finite dimension. The dynamic models considered include both linear and nonlinear restoring forces.

RESPONSE CHARACTERISTICS OF INTEREST

For a stochastic excitation the exact time history of some future loading cannot be predicted, nor can the exact time history of the response. Thus the processes involved must be characterized by predictable quantities. They are usually averages of a type referred to as expected values, ensemble averages, or simply mean values of some random quantity. These averages are expected values of random variables, but they are probably best understood intuitively in terms of the concept of an ensemble of possible time histories. If $X(t)$ is some stochastic function of time t (a random process), an ensemble containing all the possible time histories of $X(t)$ can exist. The expected value $E[X(t)]$ for a particular value of t is the average across that ensemble at that time.

The simplest partial description of some random response process $X(t)$ is the mean value function $m_X(t) = E[X(t)]$. This is the ensemble average of all possible response values at time t. The mean value conveys no information about the variability, or scatter, of the possible response values. In fact, in some situations it can be argued from symmetry that the mean value function is zero for all times and so gives absolutely no information.

The next level of complexity in describing random response is to consider various forms of second-moment information; that is, to consider expected values of the product of two $X(t)$ values. The most general form is the autocorrelation function for the process $\phi_X(t,s) = E[X(t)X(s)]$; this function represents the ensemble average of the product of X at time t and X at time s evaluated for each possible time history [1,2]. The m_X and ϕ_X functions can be used to derive the covariance function for the response $K_X(t,s)$; the normalized form is called the correlation coefficient. The variance $\sigma^2_X(t)$ is the special case of covariance with $s = t$.

* Professor of Civil Engineering and Mechanical Engineering, Rice University
P.O. Box 1892, Houston, Texas 77251
** Professor of Civil Engineering, Rice University

The quantity $\sigma_X(t)$ provides information about the variability of the response at that time. Possibly even more important, however, is the fact that the second moment functions contain information about the possible shapes of the time histories. For example, if the time histories are almost periodic, the second moment functions $\phi_X(t,s)$ and $K_X(t,s)$ are almost periodic functions of the time difference, $s - t$. Similarly, certain types of smoothness of time histories can be shown to be related to smoothness of the second moment functions.

Power spectral density is another commonly used form of second-moment information [2,3]. Although more general definitions exist [4,5], the term usually refers to a situation in which $X(t)$ is said to be covariant stationary. This means that the $\phi_X(t,s)$ function would be unchanged by relocation of the origin of the time axis. The implication is that $\phi_X(t,s)$ is the same as some function with a single argument, which will be written as $R_X(s-t)$. The power spectral density $S_X(\omega)$ is then a Fourier transform of the $R_X(\tau)$ function. The practical significance is that the power spectral density gives a frequency decomposition of the stochastic process $X(t)$. Large harmonic components in the $X(t)$ time histories correspond to harmonic components in the $R(\tau)$ function and to large values of $S_X(\omega)$ at the frequency ω of the harmonic components. The normalization of $S_X(\omega)$ is such that the integral of the function over all frequencies gives the mean squared value of X.

All of the concepts of second-moment analysis can be extended to higher order moments, but the physical significance becomes less intuitively obvious. It is important to realize that first-moment, or mean value, and second-moment information provide only a partial description of a process. For example, if two process $X(t)$ and $Y(t)$ have identical first and second moment functions, but $E[Y^k(t)] > E[X^k(t)]$ for $k > 2$, $Y(t)$ is more likely to take on very large (positive or negative) values than is $X(t)$. This may be important because predicting the likelihood of very large responses that can cause failure of a system is often an objective.

All of these probabilistic averages can be viewed as derived, rather than fundamental, characteristics of a process. A more fundamental and complete description involves probability distribution. If the probability distributions of $X(t)$ are known, the probability of any particular response level can be computed directly. For example, $F_X(u;t)$ can be used as the probability of $X(t)$ being less than or equal to any particular value u, corresponding to the fraction of the ensemble of time histories having $X(t) < u$. Furthermore, sufficient knowledge of probability distributions allows computation of all of the moment functions mentioned above. Unfortunately, probability distribution information is rarely known with confidence. Simplifying assumptions are commonly made to allow estimates of probabilities from knowledge of moments. Alternatively, the Chebyshev inequality can be used to derive rigorous -- but generally very crude -- bounds on the probability of large responses [6-8].

In order to better define the random vibration problem, let $P(t)$ denote the excitation of some linear or nonlinear system and $X(t)$ denote the response. The goal is to compute response characteristics such as mean value, covariance function, power spectral density, and probability distribution for $X(t)$ from knowledge of similar characteristics for $P(t)$ and properties of the system.

RESPONSE OF LINEAR SYSTEMS

Most of the topics presented here regarding stochastic analysis of linear systems are readily available in common reference books [1-3, 6-11]. In addition, pertinent results can be found in general review publications on random vibrations [12-15].

One general approach for random vibration analysis of linear systems is to use the results of deterministic analysis. For any of the possible $P(t)$ time histories an expression for $X(t)$ can be written as a functional of $P(t)$. In its simplest form this is the Duhamel convolution integral. It allows generation of an ensemble of response time histories from which characteristics of $X(t)$ can be found. The moments of $X(t)$ can be computed by substituting the Duhamel integral into the particular expectation desired. In addition to initial conditions, only the mean value function for $P(t)$ must be known in order to predict the mean value function for $X(t)$. Similarly, the covariance function $K_X(t,s)$ depends only on $K_p(t,s)$ and initial conditions; the same property extends to any order moment property. However, computation of the response variance $\phi^2_X(t)$ requires knowledge of the excitation covariance $K_p(t,s)$ rather than excitation variance only.

The Duhamel integral can be viewed as writing $X(t)$ as a superposition of responses due to various time increments of $P(t)$. Performing this time domain superposition requires knowledge of the impulse response function $h(t)$ for the linear system. The Fourier transform of the Duhamel integral provides a relationship between the

corresponding frequency components of P(t) and X(t) for each frequency ω. In fact, this simple relationship involves only multiplication by $H(\omega)$, which is the harmonic response function for the linear system. A time history of the X(t) response involves a superposition in the frequency domain in the form of an inverse Fourier transform integral.

The power spectral density $S_X(\omega)$ is a frequency domain representation of the second moment of X(t); therefore, $S_X(\omega)$ can be written in terms of $S_p(\omega)$ and $H(\omega)$. Thus, the second moment calculations for a covariant stationary X(t) can be done by either time domain or frequency domain calculations, just as the deterministic problem can be done by either of these two approaches. The choice between the two procedures is somewhat arbitrary and is usually affected by the form of information given for P(t) and the form of information needed for X(t). Higher order response moments can also be evaluated from analysis in either the time domain or the frequency domain (16). The frequency analysis involves generalization of the usual power spectral density concept to include Fourier transforms of higher order moment functions.

The probability distribution for X(t) is not readily obtainable from the superposition integrals of either time domain or frequency domain. In certain special cases the results are obvious. If P(t) has a particular form, called the normal (or Gaussian) distribution, X(t) also has a normal distribution. The normal distribution is such that the probability functions -- e.g., $F_X(u;t)$ -- are completely determined if the first and second moments are known. Thus, if P(t) has the normal form, finding $m_X(t)$ and $K_X(t,s)$ provides complete probability information for the response. Fortunately, this distribution is often adequate for predicting various probabilities because many physical processes are approximately normal.

Sometimes, however, the normal distribution is not sufficiently accurate. In such cases third or fourth moments can be used to characterize deviation away from a normal distribution. In fact, if P(t) has a distribution of a special form that can be characterized by the first k moments, X(t) also has that form of distribution. (This special form of distribution is one in which the so-called cumulant functions of the process are zero for orders greater than k, where a j^{th} order cumulant is a particular form of the j^{th} moment function for the process.) Thus computation of k response moments provides a complete probability description of X(t) for this excitation. This is an extension of the usual normal distribution, which is the special case with k = 2.

State space analysis provides a fundamentally different approach for determination of the response moments of linear systems. The first step is to derive simultaneous equations governing the moments of X(t) by multiplying various response quantities times the differential equation governing X(t) and taking expectations. The moments are found from solving the simultaneous equations. If the moments are nonstationary, the simultaneous equations involve first order derivatives of the moments with respect to time, but only algebraic equations need be solved to obtain the values of stationary moments corresponding to any instant in time.

The state space method is usually applied only when X(t) is the solution of a linear differential equation with a nonhomogeneous part W(t) of the type called white noise; it is a very chaotic process that is independent of itself at any two distinct values of time. In this situation X(t) is said to have the Markov property. This means that, if $X(t_0)$ is known, X(t) for $t > t_0$ is conditionally independent of X(s) for $s < t_0$. In some situations the state space method can be applied to structural problems by approximating the structural excitation P(t) as a white noise. In other problems the method can be applied by considering P(t) as the response of some linear filter to a white noise excitation. In the latter case X(t) becomes the response to white noise of a combined linear system that includes the filter in series with the original structural system.

The most common use of state space analysis is to find second moments of the response. The differential equation governing X(t) is usually rewritten as a set of simultaneous first order differential equations; they can be viewed as a matrix differential equation governing a vector of response quantities. The response vector is multiplied by this matrix equation; expectations are taken to yield a form called the Lyapunov covariance matrix equation. Other formulations of the method can be used to find equations for more general moment functions, such as $K_X(t,s)$ for second moments involving more than one instant of time [17] or for higher order moments [16].

Still another fundamentally different method of analysis uses the Kolmogorov equations (14). These partial differential equations contain derivatives with respect to time and the state variables. Either of the two forms (forward and backward) governs the probability distribution of the incremental change in X(t) between two dis-

tinct times. The original differential equation governing $X(t)$ is used only to derive coefficients in the Kolmogorov equations. The so-called forward Kolmogorov equation is also referred to as the Fokker-Planck equation. Application of the Kolmogorov equations requires that $X(t)$ has the Markov property, as noted for state space analysis.

A Kolmogorov solution gives the evolution (or diffusion) of the probability distribution of the response. This evolution can be compared to the state space approach in which equations governing evolution of the moments of the response are derived. Thus, at least in principle, the Kolmogorov equation provides more information than a finite number of state space equations because knowledge of the probability distribution allows computation of all moments of the response. In fact, certain equations governing the moments of the response can be derived directly from a Kolmogorov equation even if the solution of that equation is not known.

The Kolmogorov equations are usually applied only when certain simplifications can be made in order to limit the derivatives in the equations to second order. One such simplification -- assuming that the excitation of the system has the normal probability distribution -- assures that the response of a linear system is also normally distributed. Knowledge of only first and second order moments of the response thus provides a complete description of the probability distribution. In this special case, therefore, the Kolmogorov equations for the probability distribution of $X(t)$ for a linear system provide information that might also be obtained from a fairly simple state space analysis. Another situation in which an appropriate simplification of the Kolmogorov equations occurs is when a lightly damped system is excited by a broadband excitation, and terms proportional to second or higher powers of damping are neglected [14].

For other problems Kolmogorov analysis yields results not readily obtained in other ways. One example involves determination of the probability distribution of the amplitude of a response [18]. Another problem for which Kolmogorov analysis is useful is the probability distribution of the time for $X(t)$ to first reach some specified state (perhaps a failure state). This is the so-called first-passage problem [19]. In Kolmogorov analysis this problem can be handled by making the specified state an absorbing state; the probability of being in the state at time t is then identical to the probability that the time of first arrival is not greater than t. Introduction of such an absorbing state into the Kolmogorov analysis involves no more than changing the boundary conditions on the differential equation.

The form of the equations for a linear system can significantly affect the difficulty of applying the various forms of stochastic analysis. For multi-degree-of-freedom (MDF) systems, for example, any form of modal superposition is easier if the system has uncoupled (classical) modes of vibration. In modal superposition the total response of the linear system is written as a sum of modal responses. If the modes are uncoupled, each mode behaves exactly like a single-degree-of-freedom (SDF) system; coupled modes are not as simple as SDF systems.

One application of modal superposition involves finding either the impulse response function $h(t)$ or the harmonic response function $H(\omega)$ for the entire system as a sum of such response quantities for the modes. Stochastic analysis then uses $h(t)$ in the Duhamel integral or $H(\omega)$ to find frequency components without explicit reference to the MDF nature of the system. Alternatively, expressions for the stochastic response of each mode can be obtained, followed by superposition of stochastic modal response quantities. In addition to the individual modal responses, however, cross-correlations between various modal responses must be considered.

The governing simultaneous equations in the state space method of analysis can be written either for an entire MDF system or for modal response quantities. Modal coupling causes no difficulty in formulating these equations for the entire system. Thus, it is convenient to use this method with any standard algorithm to solve the simultaneous equations for numerical values of the response moments for an MDF system with coupled modes. The method is perhaps less desirable than the Duhamel integral if analytical expressions for the response quantities are desired.

RESPONSE OF NONLINEAR SYSTEMS

Linear dynamic models are appealing for structural engineering applications because they are relatively easy to analyze compared to nonlinear models. Furthermore, for many problems linear models yield qualitatively accurate results that are only marginally incorrect quantitively. However, in several cases involving strong dynamic excitations, such as seismic loads, structural components are expected to exhibit severely nonlinear behavior. In addition, nonlinearity may be involved in the determination of certain structural loads. For example, loads induced by ocean waves are nonlinear functions of both

water velocities and response velocities. In general, nonlinear behavior of a structural system is associated either with material or geometrical aspects. Furthermore, nonlinear structural responses can be classified as either elastic or inelastic.

The advent of modern computational methods and maturation of the field of random vibration have led to the development of methods for both exact and approximate analyses of stochastically-excited nonlinear systems. In many respects these techniques are conceptually similar to those already described for linear systems.

The class of problems of nonlinear random vibrations that lend themselves to exact solutions is strikingly limited. If the excitation can be modeled reasonably accurately as a white noise, the structural response can be taken as a Markovian process that satisfies a Kolmogorov equation. The most general class of SDF problems for which a stationary or steady-state solution can be determined exactly has been given [14]. Although this equation includes several standard problems, for example, the Duffing oscillator, it does not include some crucial models of vibrating structural systems; e.g., the Van der Pol oscillator. It is safe to state that exact solutions are rare or nonexistent for the nonstationary, or transient, probability distributions of Markovian models of nonlinear structural systems. This comment is particularly appropriate with regard to the solution of MDF nonlinear structural systems exposed to random excitation.

An alternative approach to determining with any preselected reliability the exact response statistics of nonlinear structural systems exposed to random excitation is based on procedures involving purely numerical random experiments; these experiments are commonly known as Monte Carlo simulations [20,21]. The qualifier Monte Carlo is attributable to von Neumann and his collaborators, who introduced it as a code name for their classified work on neutron diffusion problems during World War II. In connection with nonlinear structural dynamics problems, the concept of the ensemble average is the theoretical basis for use of Monte Carlo simulation. Specifically, a large number of time history samples are numerically simulated and are considered representative of an infinite ensemble of possible time histories. Although in the past Monte Carlo studies were conducted by using either analog or digital computers, digital computers are now used almost exclusively. The fundamental element of any digital Monte Carlo study is generation of pseudo-random numbers with a preselected probability density. The word pseudo calls attention to the fact that the numbers are reproducible; the sole element of randomness is that they form an erratic sequence with an extremely long period of return.

Proper processing of pseudo-random numbers can yield samples that belong to ensembles for random excitations with preselected marginal probability densities and spectral characteristics [4,5]. After a single sample of the random excitation is generated, the structural response can be computed by any standard commercially available code for numerical integration of nonlinear structural dynamics problems. Other excitation samples can then be generated and used to obtain structural response samples. If a large number of records of the response can be generated, the derived ensemble can be used to determine with good accuracy the statistics of the nonlinear structural response.

Unfortunately, the degree of fluctuation of the statistics determined by this procedure decreases with the square root of the numbers of records simulated, and the cost of the computation increases almost linearly with the number of records. Thus, Monte Carlo simulations, especially for MDF systems can be costly in terms of computational time. However, in many situations time averages over a single adequately long response sample can be used as a substitute for ensemble averages. The equivalence of time averages and ensemble averages is called ergodicity; in most practical situations it is assumed rather than proved. Time averages can economize computation time by avoiding the simulation of a large number of response records. Ergodicity, for example, can be used as an approach to the dynamic analysis of structures exposed to ocean wave loads that are described probabilistically. On the contrary, this approach is not logical in probabilistic analyses of structural responses to seismic loads that are inherently transient and thus non-ergodic.

The great difficulty in dealing exactly with problems of nonlinear vibration of stochastically excited structural systems has led to an intensified effort to develop methods of approximate analysis [6,8,11,15,18,22-28]. These methods can be classified into two categories [22]. One category includes methods applicable to the solution of such partial differential equations as the Kolmogorov equations that describe the evolution of the probability density function of the response. The other class includes methods directly applicable to the differential equation that governs the motion of the structure.

The techniques directly applicable to the Kolmogorov equations are for the most part limited to SDF. In connection with structural engineering problems, the methods applicable to the equation of motion deserve greater consideration. Three of the methods considered below are the perturbation method, the stochastic averaging method, and the statistical linearization method.

The perturbation technique was developed for weakly nonlinear systems; it is an adaptation to random vibration of the well known asymptotic method that is applicable for deterministically excited systems [6,8,22-24]. The nonlinearity of the system is quantified by a small parameter ε ; system response is expressed in a series involving terms of ascending order of ε . Collecting terms of like power in ε leads to a cascade of linear random vibration problems that can be solved sequentially. This versatile technique can treat stationary and nonstationary random vibration problems. However, due to practical considerations, it is seldom used in a format that involves terms higher than first order in the parameter ε .

Another technique for random vibration analysis of nonlinear systems, commonly referred to as stochastic averaging [8,11,14,18,19,29], is applicable when the damping of a structure is light and the excitation is broad-band (nearly white noise). Stochastic averaging has been introduced on a physical basis [11] and has been examined on a mathematical basis by several researchers. The main concept is to extend averaging techniques used in deterministic vibrations to stochastic dynamics so as to obtain a first order differential equation of a Markovian model of an appropriate envelope of the response. The most common envelope is the total energy of the oscillatory system. The procedure can also be used to address both stationary and nonstationary problems. In fact, it can provide reliable approximate analytical stationary solutions for a broad class of problems.

The method of statistical linearization has been introduced in the field of random vibration as an extension of the well known Krylov-Bogoliubov equivalent linearization technique for deterministic vibration problems [6,8,22,25,27,28]. The method replaces in an optimal manner the nonlinear system by an equivalent linear system, the stiffness and damping parameters of which depend on the response statistics. Any of the techniques available for linear random vibration analysis (as discussed in the preceding section) is then used to determine the statistics of the response of the equivalent linear system. Finally, this information is used to estimate the statistics of the original nonlinear system.

Because the stiffness and damping of the equivalent linear system depend on the response statistics, the procedure requires solution of a set of nonlinear algebraic equations (stationary problems) or differential equations (nonstationary problems). Solution can be accomplished by using any commonly available software package for numerical solution of algebraic or differential equations.

This method is reasonably accurate and remarkably versatile. Indeed, the approximate solution error is not excessive. Further, the method can be applied for MDF structural systems that are exposed to either stationary or nonstationary excitation and exhibit elastic or inelastic nonlinearity. The most expeditious procedure for dealing with inelastic systems is to use differential equations. This approach leads to an augmented dynamic system that combines the equation of motion of the original system and differential equations representing structural hysteresis [30]. The method of statistical linearization has been used extensively in structural engineering applications, particularly in connection with earthquake engineering and offshore engineering problems.

CONCLUDING REMARKS

Several methods of random vibration analysis appropriate for structural engineering applications have been discussed. Any of these methods deals either with the equation of motion of the structure or with partial differential equations governing the evolution of various probability densities of the response. The choice of a stochastic method may be somewhat arbitrary. The relative advantages and disadvantages must be considered, but personal preference for or familiarity with one method or another also plays a part.

ACKNOWLEDGEMENTS

The first author gratefully acknowledges partial support of this work by an NSF-PYI-84 award, and by matching funds from Brown and Root, Inc.; Conoco, Inc.; Dow Chemical Company; NL Industries, Inc.; Tracor, Inc.; and Shell Development Company.

REFERENCES

1. Bendat, J.S. and Piersol, A.G., Random Data: Analysis and Measurement Procedures, Wiley-Interscience, NY (1971).

2. Bendat, J.S. and Piersol, A.G., Engineering Applications of Correlations and Spectral Analysis, Wiley-Interscience, NY (1980).

3. Newland, D.E., An Introduction to Random Vibration and Spectral Analysis, Longmans, London (1975).

4. L.H. Koopmans, The Spectral Analysis of Time Series, Academic Press, NY (1974).

5. M.B. Priestley, Spectral Analysis and Time Series, Vols. 1 and 2, Academic Press, NY (1981).

6. Lin, Y.K. Probabilistic Theory of Structural Dynamics, Krieger, NY (1977).

7. Elishakoff, I., Probabilistic Methods in the Theory of Structures, Wiley InterScience, NY (1983).

8. Nigam, N.C., Introduction to Random Vibrations, the MIT Press, London (1983).

9. Crandall, S.H. and Mark, W.D. Random Vibration in Mechanical Systems, Academic Press, NY (1963).

10. Robson, J.D., An Introduction to Random Vibration, Edinburgh University Press (1963).

11. Stratonovich, R.L., Topics in the Theory of Random Noise, Vols. 1 and 2, Gordon and Breach, NY (1963).

12. Crandall, S.H. "Random Vibration," Appl. Mech. Rev., 12, pp 739-742, (1959).

13. Crandall, S.H. and Zhu, W.Q., "Random Vibration: A Survey of Recent Developments," J. Appl. Mech., Trans., ASME, 50, pp 953-962 (1983).

14. Huang, T.C. and Spanos, P.D. eds., Random Vibrations, AMD-Vol 65, ASME, NY (1984).

15. Vanmarcke, E.H. "Some Recent Developments in Random Vibration," Appl. Mech. Rev., 32, pp 1197-1202, (1979).

16. Lutes, L.D. and Hu, S-L. J., "Nonnormal Stochastic Response of Linear Systems," ASCE J. Engrg. Mech. (to be published).

17. Spanos, P.D., "Spectral Moments Calculation of Linear System Output," J. Appl. Mech., Trans. ASME, 50, pp 901-903, (1983).

18. Spanos, P-T. D., "Approximate Analysis of Random Vibrations Problems through Stochastic Averaging", IUTAM Symp. Random Vib. Reliabil., Frankfurt (Oder), East Germany, October 31-November 6, 1982, K. Hennig (ed.), pp 327-337, Akademie-Verlag.

19. Roberts, J.B., "First-Passage Probabilities for Randomly Excited Systems: Diffusion Methods," J. Probabil. Engrg. Mech., 1 (3) (1985).

20. Shinozuka, M., "Monte Carlo Solution of Structural Dynamics," Computers Struc., 2, pp 885-874 (1975).

21. Rubinstein, R.Y., Simulation and the Monte Carlo Method, Wiley, NY (1981).

22. Caughey, T.K., "Non-Linear Theory of Random Vibrations," Adv. Appl. Mech., Vol. 11, pp 209-253 (1971).

23. Dinca, F. and Teodosiu, C., Nonlinear and Random Vibrations, Academic Press, NY (1973).

24. Iwan, W.D., "Application of Non-Linear Analysis Techniques," Appl. Mech. Earthquake Engrg., ASME-AMD8, W.E. Iwan (ed.), pp 135-161 (1974).

25. Spanos, P.D. "Stochastic Linearization in Structural Dynamics," Appl. Mech. Rev., 34, pp 1-8, (1981).

26. Roberts, J.B. "Response of Non-Linear Mechanical Systems to Random Excitation; Part I: Markov Methods," Shock Vib. Dig. 13 (4), pp 17-28 (1981).

27. Roberts, J.B., "Response of Non-Linear Mechanical Systems to Random Excitation; Part II: Equivalent Linearization and Other Methods," Shock Vib. Dig., 13 (5), pp 15-29 (1981).

28. To, C.W.S., "The Response of Non-Linear Structures to Random Excitation," Shock Vib. Dig., 16 (4), pp 30-33 (1984).

29. Roberts, J.B. and Spanos, P.D., "Stochastic Averaging: An Approximate Method of Solving Random Vibration Problems," Intl. J. Non-Linear Mech. (1985).

30. Wen, Y-K., "Stochastic Response and Damage Analysis of Inelastic Structures," J. Probabil. Engrg. Mech., 1 (1), pp 49-57 (1985).

LITERATURE REVIEW: survey and analysis of the Shock and Vibration literature

The monthly Literature Review, a subjective critique and summary of the literature, consists of two to four reviews each month, 3,000 to 4,000 words in length. The purpose of this section is to present a "digest" of literature over a period of three years. Planned by the Technical Editor, this section provides the ***DIGEST*** reader with up-to-date insights into current technology in more than 150 topic areas. Review articles include technical information from articles, reports, and unpublished proceedings. Each article also contains a minor tutorial of the technical area under discussion, a survey and evaluation of the new literature, and recommendations. Review articles are written by experts in the shock and vibration field.

THEORETICAL STUDIES ON FLEXURAL WAVE PROPAGATION IN BEAMS: A COMPREHENSIVE REVIEW -- PART I: HISTORICAL BACKGROUND

M.M. Al-Mousawi*

Abstract. A comprehensive review related to the problems of flexural wave propagation in beams is presented in three parts. Part I is a historical background. Part II describes the use of Timoshenko beam theory, including the effect of shear distortion and rotatory inertia, for vibrational and transient analysis of beams. Part III covers elastic stress wave propagation in beams with discontinuities of cross section.

The behavior of structural elements under impact loading is a subject of great interest in dynamical structural analysis. When forces are applied to an elastic body over a very short period, the response should be considered in terms of wave propagation theory.

Beams are among the simplest engineering structures, but the propagation of waves can be complicated by such boundaries as end surfaces and abrupt changes that cause reflections.

The study of transient waves has important implications and applications for structures subjected to impact. The revival of interest in elastic wave propagation during the last three decades has been possible because of the rapid development of computing facilities and experimental equipment.

The problems of flexural wave propagation in beams have not been so extensively treated as have the problems of longitudinal wave propagation. This is due to the complexities involved in the propagation of flexural waves and their dispersive character.

The Euler-Bernoulli [1] theory is inadequate for the study of transient bending waves because it leads to the physically impossible conclusion that disturbances are propagated instantaneously; the theory also neglects the effects of shear deformation and rotatory inertia.

An exact theory based on the theory of elasticity dates from the 19th century; Pochhammer [2] and Chree [3] investigated the case of infinitely long beams of circular cross section. However, their equations cannot be applied to semi-infinite and finite bars with arbitrarily prescribed end conditions. In addition, their solutions involve such complicated mathematics that, from an engineering point of view, they have little practical value.

The Timoshenko theory [4] is the only approximate theory that contains the essential features of the exact theory in simplified form. This theory leads to more accurate solutions than the Euler-Bernoulli theory because the effects of shear deformation and rotatory inertia are included in the governing equations. However, the Timoshenko theory provides for only two modes of transmission and consequently two branches of the dispersion curve; the exact theory provides an infinite number of modes and an infinite number of higher branches of the dispersion curve.

It is hoped that the need for an extensive review of the work that has been carried out in the field of flexural wave propagation will be met at least in part by this paper. Wave propagation in beams with discontinuities of cross section is discussed as an important practical example for structural elements. This survey of theoretical publications in the field of flexural wave propagation in beams is also intended to demonstrate the importance of the Timoshenko beam theory as a vehicle for numerical solution of such problems.

This brief history is based on books that include a comprehensive survey of the history of the theory of elasticity [5,11,12]. The theory of transverse waves in elastic solids had its beginnings in the 18th century work of Leonard Euler and Daniel Bernoulli. They derived the partial differential equation governing the flexural vibration of a bar by varying the strain-energy function; they had already used this function to express the work done in bending.

The concept of transverse vibration transmitted through a medium was originally based on a theory developed by Fresnel in 1816. He used the concept of transverse waves to explain the propagation of light, which was at that time

* University of Aberdeen, Department of Engineering, Kings College, Aberdeen, Scotland

thought to be a disturbance propagating in an elastic ether. Navier investigated in 1821 the theory of transverse body waves. His general equations of equilibrium and vibration of elastic bodies considered forces acting between individual molecules of a deformed elastic body. A year later Cauchy elaborated much of the theory of elasticity including the dynamic equations of motion. He introduced the concepts of strain and stress that greatly simplified the derivation of the equations. His stress-strain relationships for isotropic materials were based on two assumptions: that the relationship is linear and that the principal planes of stress are normal to the principal axis of strain. Cauchy later treated the problem of longitudinal impact of two rods of the same material and cross section. He wrongly concluded that an impulse terminates whenever the two bars have different velocities of impact.

Poisson in 1829 discussed three equations of equilibrium and three conditions at the boundary. He proved that these equations are not only necessary but also sufficient to assure the equilibrium of any portion of the body. He succeeded in integrating the equations of motion and showed that, if a disturbance is produced in a small portion of a body, two kinds of waves result. The dilatational wave was associated with particle motion normal to the wave front and accompanied by a volume change. The distortional wave was associated with particle motion tangential to the wave front where distortion occurred without volume change. The first and faster wave is also called the irrotational wave; the other wave is also called the equivoluminal or transverse wave.

It was soon realized that the problem of wave propagation in an elastic solid should be investigated in ways other than those used for normal modes of vibration. Poisson and Ostrogradsky used a synthesis method of simple harmonic solutions of the initial distribution of displacement and velocity to determine displacement at any point and at any time.

Poisson attempted in 1833 to solve the problem of longitudinal impact of two bars previously treated by Cauchy. Poisson used a method of integrating trigonometrical series; a general solution was extremely difficult. An error in the analysis led him to conclude that, when bars are of the same material and cross section, they never separate unless they are equal in length.

Around the middle of the 19th century Seebeck presented an equation for the transverse displacement of an elastic bar. He showed that the difference in E values obtained by statical and vibrational methods is extremely small. He did not consider the effect of angular rotation of the cross section of the rod [5].

Baree de Saint-Venant made wide-ranging contributions to the theory of longitudinal and transverse impact. In 1853 he considered the problem of a central impact on a simply supported beam of uniform cross section and based his solution on different modes of vibration. His calculations of deflection at the middle coincided with earlier ones by Cox, who had considered only the first and most important term of a series representing the maximum deflection. However, Saint Venant's solution for the problem of transverse impact was not complete because he did not consider local deformation at the point at which an impinging ball strikes the beam. In addition, his assumption that the ball remained in contact with the beam until its deflection was greatest is not realistic. Furthermore, the solution did not apply if the bar was very long and the striking ball had little weight but a very high impact velocity.

However, Saint-Venant did make important contributions to the theory of elasticity. He examined the assumptions of the elementary Euler-Bernoulli theory of bending -- that the cross section of a beam remains plane during deformation and that the longitudinal fibers of a beam are in a state of simple tension or compression. Saint-Venant showed that these two assumptions are fulfilled only in uniform bending when the beam is subjected to two equal and opposite couples applied at the end. The assumptions are not applicable to the case of transverse bending, in which shearing stresses cause warping of the cross section; the cross section does not remain plane during bending. Saint-Venant pointed out the accuracy of the Euler-Bernoulli theory for flexural vibration and suggested important corrections. He was not only interested in statical stress-analysis but also studied the dynamical action of loads moving along a beam and various types of impact problems that produce lateral and longitudinal vibrations.

Saint-Venant also formulated the principle that carries his name. According to this principle, the effects produced by deviation from assigned laws of loading are unimportant except close to the ends of a bent beam, where the loading produces merely local perturbation. The practical condition for which the principle is valid is that the length of a beam should be many times greater than the largest cross sectional dimension.

Bresse [6] discussed the longitudinal and lateral vibrations of rods and considered moment of inertia and shear distribution over the cross section in connection with work on arched structures. He suggested correction terms for both rotatory inertia and transverse shear. However, his equation for transverse vibration of uniform simply supported beams included a term that accounted only for the effect of rotatory inertia.

In the 1860s Saint-Venant used the equation of vibration to study the collision of two rods of the same material and with the same cross section; he used arbitrary functions for various impact velocities of bars of different length. He derived the most important relation for the duration of impact as $2l/c$, where l is the length of the shorter bar and c is the velocity of sound ($\sqrt{E/\zeta}$). Saint Venant also discussed the problem of longitudinal impact of beams in the form of truncated cones. He obtained solutions by lengthy trigonometrical series. His graphic solutions for values of velocity and displacement can be considered the first x-t diagrams constructed for impact problems.

Saint-Venant also presented trigonometrical solutions for the problems of a prismatic bar fixed at one end and subjected to the influence of transient compressional wave due to a longitudinal impact at the other end. His solution was based on the assumption that the striker becomes rigidly attached to the end. He summed the first few terms of the trigonometric series and was able to find the motion of the bar end. But the series used to calculate stresses did not converge rapidly enough to allow the computation of an accurate result. He pointed out the need to use a closed form expression for the solution instead of infinite series.

Solutions in terms of finite discontinuous functions were obtained independently in the early 1880s by Boussinesq, Sebert and Hugoniot and Saint-Venant. Saint-Venant used his solutions to graphically represent successive stages of the longitudinal impact of a bar for entire duration of impact as well as various ratios of the mass of the bar to that of the striking mass.

Saint-Venant investigated wave propagation in bars, basing his research in part on the assumption that bars made simultaneous contact over the entire area of the end; this condition is extremely difficult to achieve. A modification of the theory suggested by Hertz [7] was based on an electrostatic analogy for the contact of two elastic bodies with curved contact surfaces under the action of a static compressive force; he used the analogy as an approximation for the actual dynamic loading.

The Saint-Venant theory sufficiently approximated the state of strains and stresses at considerable distances from the point of loading and support. The impact forces in the immediate vicinity of the impact point could be determined more successfully by the Hertzian theory. Saint-Venant then presented a detailed theory of the transverse impact of bars. He included analytical and numerical solutions for various problems of bars vibrating transversely with loads attached.

Boussinesq suggested in 1895 a general wave solution of the equation of motion for longitudinal impact in the form of forward and backward traveling waves. He also used discontinuous functions to study the problem of transverse vibration of a uniform bar for various types of loading.

Lord Rayleigh [8] discovered a third type of wave that propagates parallel to the surface with a velocity slightly less than the velocity of a distortional wave. This wave, called a Rayleigh surface wave, decays exponentially toward the interior of the body.

Pochhammer [2] used the general theory of elasticity to investigate longitudinal, torsional, and flexural vibrations of an infinitely long beam of uniform circular cross section. He used an infinite harmonic wave train to express displacements in the general transcendental frequency equations as a product of sinusoidal and Bessel functions. For the lowest branch of the frequency equations he obtained first and second approximations for extensional (longitudinal) waves and a first approximation for flexural waves. It is extremely difficult to use these complex equations to study transient flexural wave propagation problems, but they have been guides in the use of approximate wave theories. The same equations were given by Chree [3].

Wave propagation involving dispersion is important for investigations related to flexural wave problems. Cauchy and Green discussed the propagation of plane waves through a crystalline medium and obtained equations for the velocity of propagation in the 1830s. Hamilton investigated the velocity of propagation of a finite train of waves in a dispersive medium in his work on the theory of light. Kelvin's group method of approximating integral representations of dispersive waves was included in his work on water waves in 1887.

Lord Rayleigh [8] discussed the problem of lateral vibration of rods; he included a correction for the rotatory inertia in the equation of motion. This correction is usually attributed to him, although it was originally given by Bresse as early as 1859.

Lamb [9], who was concerned with the investigation of flexural waves in plates, pointed out the inadequacy of the Euler-Bernoulli theory. The theory predicts that the effect of a localized disturbance begins instantaneously at all distances.

Timoshenko [4,10] corrected the Euler-Bernoulli equation for flexural waves by including the effect of shear deformation in addition to the correction term for rotatory inertia. Although the shear correction term was originally suggested by Bresse, Timoshenko was the first to include it in an approximate theory dealing with flexural wave propagation in a rod. This theory forms the basis of the present investigation.

REFERENCES

1. Graff, K.F., Wave Motion in Elastic Solids, Clarendon Press, Oxford (1975).

2. Pochhammer, L., "Uber die Fortpflanzungsgeschwindigkeiten kleiner Schwingungen in einem unbegrenzten isotropen Kreiscylinder," Z. Math., 81, pp 33-61 (1876).

3. Chree, C., "The Equations of an Isotropic Elastic Solid in Polar and Cylinder Coordinates, Their Solution and Application," Trans. Camb. Phil. Soc., 14, pp 250-369 (1889).

4. Timoshenko, S.P., "On the Correction for Shear of the Differential Equation for Transverse Vibration of Prismatic Bars," Phil. Mag. 41 Ser. 6, pp 125-131 (1921).

5. Todhunter, I. and Pearson, K. A History of the Theory of Elasticity, Vol. II, Pts. I, II, Dover Publ., NY (1983).

6. Bresse M., Cours de Macanique appliquee, (Successeur de Mallet - Bachelier), Paris (1866).

7. Hertz, H. "Uber die Beruhrung fester elastischer Korper," Z. reine angew. Math. (Crelle), 22, pp 156-171 (1882).

8. Rayleigh, J.W.S., The Theory of Sound, Vol. I, 1894, Dover Publ., NY, (1943 reprint).

9. Lamb, "On Waves in an Elastic Plate," Proc. Royal Soc. London, 93, Ser. A, pp 114-128 (1917).

10. Timoshenko, S.P. "On the Transverse Vibrations of Bars of Uniform Cross Section," Phil. Mag., 43, Ser 6, pp 125-131 (1922).

11. Love, A.E.H., A Treatise on the Mathematical Theory of Elasticity," Cambridge Univ. Press, 4th ed. (1927).

12. Timoshenko, S.P. History of Strength of Materials, McGraw Hill, NY, (1953).

13. Davies, R.M., "A Critical Study of the Hopkinson Pressure Bar," Phil. Trans. Royal Soc. London, 240, Ser. A, pp 375-457 (1948).

14. Goens, E. "Uber die Bestimmung der Elastizitatsmodulus von Staben mit Hilfe von Biegungsschwingugen," Annal. Physik, 5 (11), pp 649-679 (1931).

15. Davies, R.M., "The Frequency of Transverse Vibration of Loaded Fixed-Free Bars," Phil. Mag., 23, Ser. 7, pp 562-573 (1937).

16. Kruszewski, E.T., "Effect of Transverse Shear and Rotatory Inertia on the Frequency of a Uniform Beam," NACA Tech. Note 1909 (July 1949).

17. Sutherland, J.G. and Goodman, L.E. "Vibrations of Prismatic Bars including Rotatory Inertia and Sher Corrections," Tech. Rep., Univ. Illinois, Dept. Civil Engrg. (1951).

18. Traill-Nash, R.W. and Collar, A.R., "The Effects of Shear Flexibility and Rotatory Inertia on the Bending Vibrations of Beams," Quart. J. Mech. Appl. Math., 6, pp 186-222 (1953).

19. Anderson, R.A., "Flexural Vibrations in Uniform Beams According to the Timoshenko Theory," J. Appl. Mech., Trans. ASME, 20, pp 504-510 (1953).

20. Dolph, C.L. "On the Timoshenko Theory of Transverse Beam Vibrations," Quart. J. Appl. Math., 12 (2), pp 175-187 (1954).

21. Howe, C.E. and Howe, R.M., "Application of the Electronic Differential Analyzer to the Oscillation of Beams, Including Shear and Rotatory Inertia," J. Appl. Mech., Trans ASME, 22, pp 13-19 (1955).

22. Huang, T.C., "Effect of Rotatory Inertia and Shear on the Vibration of Beams Treated by the

Approximate Methods of Ritz and Galerkin," Proc., Third Natl. Cong. Appl. Mech., pp 189-194 (1958).

23. Huang, T.C., "The Effect of Rotatory Inertia and of Shear Deformation on the Frequency and Normal Mode of Uniform Beams with Simple End Conditions ," J. Appl. Mech., Trans. ASME, 28, pp 579-584 (1961).

24. Hurty, W.D. and Rubinstein, M.F., "On the Effect of Rotatory Inertia and Shear in Beam Vibration," J. Franklin Inst., 278, pp 124-131 (1964).

25. Archer, J.S., "Consistent Matrix Formulations for Structural Analysis Using Finite-Element Techniques," AIAA J., 3 (10), pp 1910-1918 (1965).

26. Kapur, K.K., "Vibration of a Timoshenko Beam Using Finite Element Approach," J. Acoust. Soc. Amer., 40 (5), pp 1058-1063 (1966).

27. Egle, D.M., "An Approximate Theory for Transverse Shear Deformation and Rotatory Inertia Effects in Vibrating Beams," NASE-CR-1317 (1969).

28. Nickel, R.E. and Secor, G.A., "Convergence of Consistently Derived Timoshenko Beam Finite Elements," Int. J. Numer. Methods Engrg., 5, pp 243-253 (1972).

29. Davis, R., Henshell, R.D., and Warburton, G.B., "A Timoshenko Beam Element," J. Sound Vib., 22, pp 475-487 (1972).

30. Thomas, D.L., Wilson, J.M., and Wilson, R.R., "Timoshenko Beam Finite Elements," J. Sound Vib., 31 (3), pp 315-330 (1973).

31. Dong, S.B. and Wolf, J.A., "Effect of Transverse Shear Deformation on Vibrations of Planar Structures Composed of Beam Type Element," J. Acoust. Soc. Amer., 53, pp 120-127 (1973).

32. Ramamurti, V. and Mahrenholtz, O., "The Application of the Simultaneous Iteration Method to Flexural Vibration Problems," Intl. J. Mech. Sci., 16, pp 269-283 (1974).

33. Thomas, J. and Abbas, B.A., "Finite Element Model for Dynamic Analysis of Timoshenko Beam," J. Sound Vib., 41, pp 291-299 (1975).

34. Thomas, D.L., Comments on "Finite Element Model for Dynamic Analysis of Timoshenko Beam," J. Sound Vib., 46 (2), pp 285-290 (1976).

35. Downs, B., "Transverse Vibration of a Uniform Simply Supported Timoshenko Beam Without Transverse Deflection," J. Appl. Mech., Trans. ASME, 43, pp 671-673 (1976).

36. Rao, V. and Kanaka, R.L., "Nonlinear Vibrations of Beams Considering Shear Deformation and Rotatory Inertia," AIAA J., 14, pp 685-687 (1976).

37. Bishop, R.E.D. and Price, W.G., "Allowance for Shear Distribution and Rotatory Inertia of Ship Hulls," J. Sound. Vib., 47, pp 303-311 (1976).

38. Timoshenko, S.P., "Zur Frage nach der Wirkung eines Strosses auf einen Balken,": Z. Math. Phys., 62, pp 198-209 (1913).

39. Arnold, R.N., "Impact Stresses in a Freely Supported Beam," IMechE, Proc., 137, pp 217-281 (1937).

40. Christopherson, D.G., "Effect of Shear in Transverse Impact on Beams," IMechE, Proc., 165, pp 176-188 (1951).

41. Lennertz, J., "Beitrag zur Frage nach der Wirkung eines Querstosses auf einen Stab," Ing. Arch., 8, pp 37-46 (1937).

42. Lee, E.H., "The Impact of a Mass Striking a Beam,", J. Appl. Mech., Trans. ASME, 7, pp A129-A138 (1940).

43. Bancroft, D., "The Velocity of Longitudinal Waves in Cylindrical Bars," Phys. Rev., 59, pp 588-593 (1941).

44. Prescott, J., "Elastic Waves and Vibration of Thin Rods," Phil. Mag., 33, Ser. 7, pp 703-754 (1942).

45. Flugge, W., "Die Ausbreitung von Beigungswellen in Staben," Z. angew. Math. Mech., 22 (6), pp 312-318 (1942).

46. Hudson, G.E., "Dispersion of Elastic Waves in Solid Circular Cylinders," Phys. Rev., 63, pp 46-51 (1943).

47. Cremer, L., "Bemerkungen zur Ausbreitung von Biegewellen in Staben und Platten," Z. angew. Math. Mech., 23, pp 291-294 (1943).

48. Davidson, T. and Meier, J.H., "Impact on Prismatical Bars," Proc. Soc. Exp. Stress Anal., 4 (1), pp 88-111 (1946).

49. Pfeiffer, F., "Uber die Differentialgleichung der transversalen Stabschwingungen," Z. angew. Math. Mech., 25/27 (3), pp 83-91 (1947).

50. Cooper, J.L.B., "The Propagation of Elastic Waves in a Rod," Phil. Mag., 38, Ser. 7, pp 1-22 (1947).

51. Uflyand, Y.S., "The Propagation of Waves in the Transverse Vibration of Bars and Plates," Prikl. Mat. Mekh. (PMM) 12, pp 287-300 (1948) (in Russian).

52. De Juhasz, K.J. "Graphical Analysis of Impact of Bar Stresses Above the Elastic Range," Parts I and II, J. Franklin Inst., 248, pp 15-49, 113-142 (1949).

53. Duwez, P.E., Clark, D.S., and Bohnenblust, H.F., "The Behavior of Long Beams Under Impact Loading," J. Appl. Mech., Trans ASME, pp 27-34 (1950).

54. Mindlin, R.D., "Influence of Rotatory Inertia and Shear on Flexural Motions of Isotropic Plates", J. Appl. Mech., Trans. ASME, 18, pp 31-38 (1951).

55. Reissner, E., "The Effect of Transverse Shear Deformation on the Bending of Elastic Plates," J. Appl. Mech, Trans. ASME, 12, pp A69-A77 (1945).

56. Mindlin, R.D. and Herrmann, G., "A One-Dimensional Theory of Compressional Waves in an Elastic Rod," Proc., 1st U.S. Natl. Cong. Appl. Mech., ASME, pp 187-191 (1951).

57. Dengler, M.A. and Goland M., "Transverse Impact of Long Beams Including Rotatory Inertia and Shear Effects," Proc. 1st U.S. Nat. Cong. Appl. Mech., ASME, pp 179-186 (1951).

58. Goland, M., Wickersham, P.D., and Dengler, M.A., "Propagation of Elastic Impact in Beams in Bending," J. Appl. Mech., Trans. ASME, 22, pp 1-7 (1955).

59. Schirmer, H., "Uber Biegewellen in Staben," Ing. Arch., 20, pp 247-257 (1952).

60. Miklowitz, J., "Flexural Wave Solutions of Coupled Equations Representing the More Exact Theory of Bending," J. Appl. Mech., Trans. ASME, 20, pp 511-514 (1953).

61. Miklowitz, J., "Elastic Wave Propagation", Appl. Mech. Rev., 13, pp 865-878 (1960).

62. Leonard, R.W. and Budiansky, B., "On Travelling Waves in Beams," NACA Rep. 1173, (Apr 1953).

63. Eringen, A.C., "Transverse Impact on Beams and Plates," J. Appl. Mech., Trans ASME, 20, pp 461-468 (1953).

64. Newman, M.K., "Effect of Rotatory Inertia and Shear on Maximum Strain in Cantilever Impact Excitation," J. Aeronaut. Sci., 22, pp 313-320 (1955).

65. Boley, B.A. and Chao, C.C., "Some Solutions of the Timoshenko Beam Equations," J. Appl. Mech., Trans. ASME, 22, pp 579-586 (1955).

66. Boley, B.A., "An Approximate Theory of Lateral Impact of Beams," J. Appl. Mech., Trans. ASME, 22, pp 69-76 (1955).

67. Boley, B.A. and Chao, C.C., "An Approximate Analysis of Timoshenko Beams under Dynamic Loads," J. Appl. Mech., Trans. ASME, pp 31-36 (1958).

68. Jones, R.P.N., "Transient Flexural Stresses in an Infinite Beam," Quart. J. Mech. Appl. Math., 8 (3), pp 373-384 (1955).

69. Barnhart, K.E. and Goldsmith, W., "Stresses in Bending During Transverse Impact," J. Appl. Mech., Trans. ASME, 24, pp 440-446 (1957).

70. Abramson, H.N. and Norman, H ., "Flexural Waves in Elastic Beams of Circular Cross Section," J. Acoust. Soc. Amer., 29 (1), pp 42-46 (1957).

71. Ripperger, E.A. and Abramson, H.N., "A Study of the Propagation of Flexural Waves in Elastic Beams," J. Appl. Mech., Trans. ASME, 24, pp 431-434 (1957).

72. Plass, H.J., "Some Solutions of the Timoshenko Beam Equations for Short Pulse Type Loading," J. Appl. Mech., Trans. ASME, 25, pp 379-385 (1958).

73. Ripperger, E.A., "Measurement of Short Bending Wave Pulse in Steel Bars," DRL-367, CM-8, pp 1-37 (July 1955).

74. Flugge, W., and Zajac, E.E., "Bending Impact Waves in Beams," Ing. Arch., 28, pp 59-70 (1959).

75. Kuo, S.S., "Bending Waves in Free-free Beams," Proc., 4th Midwest. Conf. Solid Mech., pp 457-467 (1959).

76. Kuo, S.S., "Beam Subjected to Eccentric Longitudinal Impact," Exptl. Mech., 1, pp 102-108 (1962).

77. Jones, R.P.N., "Transverse Impact Waves in a Bar Under Conditions of Plane-strain Elasticity," Quart. J. Mech. Appl. Math., 27, pp 401-421 (1964).

78. Chou, P.C. and Mortimer, R.W., "A Unified Approach to One-Dimensional Elastic Waves by the Method of Characteristics," NACA Contract Rep. 78493 (Sept 1966).

79. Chou, P.C. and Koenig, H.A., "A Unified Approach to Cylindrical and Spherical Waves by Method of Characteristics," J. Appl. Mech., Trans. ASME, 33, pp 159-167 (1966).

80. Davids, N. and Koenig, H.A., "Double Stress-wave Discontinuities in Finite Shear Corrected Beams and Plates," Proc. 10th Midwest. Conf. Mech., pp 763-779 (1967).

81. Bejda, J., "A Solution of the Wave Problem for Elastic Visco-Plastic Beams," J. Mecanique Theor. Appl., 6 (2), pp 263-282 (1967).

82. Edge, E.C., "A Study of Aircraft Arresting Hook Unit Dynamics Using Numerical Wave Propagation Method," Symp. Struc. Dynam., Loughborough Univ. Tech., UK, Paper No. D61-6.18 (1970).

83. Garrelick, J.M., "Analytical Investigation of Wave Propagation and Reflections in Timoshenko Beams," Ph.D. thesis, City Univ., NY (1969).

84. Ranganath, S., "Normal Impact of Infinite Elastic and Elastic-plastic Beams by a Semi-infinite Elastic Rod," Ph.D. thesis, Brown Univ. (1971).

85. Lee, J.P. and Kolsky, H., "The Generation of Stress Pulses at the Junction of Two Noncollinear Rods," J. Appl. Mech., Trans. ASME, 39, pp 809-813 (1972).

86. Sagartz, M.J. and Forrestal, M.J., "Bending Stresses Propagating from the Clamped Support of an Impulsively Loaded Beam," AIAA J., 10, pp 1373-1374 (1972).

87. Phillips, J.W. and Crowley III, F.B., "On the Theory of Pulse Propagation in Curved Beams," J. Sound Vib., 24, pp 247-258 (1972).

88. Morley, L.S.D., "Elastic Waves in a Naturally Curved Rod," Quart. J. Mech Appl. Math., 14 (2), pp 155-172 (1961).

89. Forrestal, M.J., Bertholf, L.D., and Sagartz, "An Experiment and Analysis on Elastic Waves in Beams from Lateral Impact," Intl. J. Solids Struc., 11, pp 1161-1165 (1975).

90. Colton, J.D., "Dynamic Fracture Process in Beams," J. Appl. Mech., Trans. ASME, 42, pp 435-439 (1977).

91. Colton, J.D., "Multiple Fracture of Beams Under Localized Impulsive Loading," J. Appl Mech., Trans. ASME, 44, pp 259-263 (1977).

92. Parker, R.P. and Neubert, V.H., "High Frequency Response of Beams," J. Appl. Mech., Trans ASME, 42, pp 805-808 (1975).

93. Huang, T.C., "Tables of Eigenfunctions Representing Normal Modes of Vibration of Timoshenko Beams," Univ. of Texas (1955).

94. Sun, C.T. and Huang, S.N., "Transverse Impact Problems by Higher Order Beam Finite Element," Computers Struc., 5, pp 297-303 (1975).

95. Tanaka, K. and Motoyama, C., "The Behavior of an Infinite Circular Bar Subjected to Impulsive Bending Load," Bull. JSME, 19, pp 248-259 (1976).

96. Tanaka, K. and Iwahashi, Y., "Dispersion Relation of Elastic Waves in Bars of Rectangular Cross Section," Bull. JSME, 20 (146), pp 922-929 (1977).

97. Nicholson, J.W. and Simmonds, J.G., "Timoshenko Beam Theory is Not Always More Accurate Than Elementary Beam Theory" discussions to the paper, J. Appl. Mech., Trans ASME, 44, pp 337-338; 357-360 (1977).

98. Davies, R.M., "Stress Waves in Solids", Survey in Mechanics," G.K. Batchelor and R.M. Davies (eds) (1956).

99. Abramson, H.N., Plass, H.J., and Ripperger, E.A., "Stress Wave Propagation in Rods and Beams," Adv. Appl. Mech., 5, pp 111-194, H.L. Dryden (ed.), Academic Press, NY (1958).

100. Curtis, C.W., "Propagation of an Elastic Strain Pulse in a Semi-infinite Bar," Intl. Symp. Stress Wave Propagation Matls., H. Kolsky and W. Prager (eds.), pp 15-43 (1960).

101. Goldsmith, W., "Impact: the Collision of Solids," Applied Mech. Rev., 16, pp 855-866 (1963).

102. Kolsky, H., "Stress Waves in Solids," J. Sound Vib., 1, pp 88-110 (164).

103. Scott, R.A., "Linear Elastic Wave Propagation. An annotated bibliography; Parts I and II," Shock Vib. Dig., 10 (2/3), pp 25-41; 11-41 (1978).

104. Kolsky, H. Stress Waves in Solids, Clarenden Press, Oxford (1953).

105. Goldsmith, W., Impact: the Theory and Physical Behaviour of Colliding Systems, Edward Arnold Publ., London (1960).

106. Johnson, W., Impact strength of Materials, Edward Arnold, London (1972).

107. Miklowitz, J., The Theory of Elastic Waves and Waveguides, North Holland, Amsterdam (1978).

BOOK REVIEWS

CORROSION FATIGUE

T.W. Crocker & B.N. Leis, eds.
ASTM Pub STP 801
ASTM, Philadelphia, PA
1983, 531 pages

Corrosion fatique occurs in atmospheric moisture and in deleterious (corrosive) environments: in the petroleum industry, in power plants and nuclear reactors, and in all forms of transportation. Linear fracture mechanics plays an important role in the interpretation of corrosion fatigue, as do chemistry and metallurgy. Metals such as aluminum, titanium, and steel alloys are affected by the presence of water during fatigue testing. Titanium and steel alloys are also affected by dry hydrogen. As stated by the editors, "This book attempts to accurately reflect the state of the art in the various aspects of corrosion fatigue."

The book consists of two major parts: the first contains papers on mechanics, metallurgy, and electrochemistry. The remaining six papers comprise the second part on engineering aspects.

The first paper deals with the relationship between fracture mechanics and corrosion fatigue, including cyclic load frequency at short cycling time. The next paper describes tests for corrosion-caused-crack initiation of four structural steels. The third paper reports anomalies of fatigue crack growth retardation in steels for offshore applications. An automated microcomputer-aided R controlling device that measures crack length and adjustment of maximum and minimum loads is described in the fourth paper.

The next paper is a report of an experimental observation of environmental contribution to fatigue crack growth. The sixth paper discusses the influence of environment and specimen thickness on fatigue crack growth data. Paper seven covers the corrosion fatigue behavior of a metal specimen in a sodium chloride solution. The eighth paper analyzes random pits in corrosion fatigue. The authors used a three-dimensional spectral evaluation of an irregularly corroded surface.

The ninth paper covers the effects of microstructure and frequency on the corrosion-fatigue crack growth in two metal specimens. The following paper covers corrosion-fatigue crack-growth characteristics of several HY-100 weldments with cathodic-potential. Residual stresses of welds were more significant than environmental effects on crack growth behavior.

The next paper is concerned with fatigue crack propagation rated in aluminum alloys. Another paper reports on the effect of microstructure and strength of small low alloy steels in cyclic crack growth in high temperature water. The following paper covers the fractography and mechanisms of environmentally enclosed fatigue crack growth propagation of steel used in reactor pressure vessels. The next paper summarizes the chemical effects of corrosion. A theoretical evaluation of oxygen concentration in corrosion fatigue cracks is the topic of one paper. The next one is a report of electromechanical aspects of corrosion fatigue in steel in a sodium-chloride solution. The last paper in Part I focuses on environmental influences in aqueous fatigue growth rates of HY-130 steel.

The first paper of Part II infers that corrosion fatigue crack growth rate data must be applied to engineering applications. The next paper details the use of specimens of one compact notched carbon steel for evaluating crack initiation design rules in high temperature water environments. The third paper is concerned with fatigue design stresses for unpainted weathering steel structures. The next paper covers corrosion fatigue of welded steel joints under narrow-band random loading in an environment representative of North Sea conditions. The fifth paper has to do with the influence of weld profile on the fatigue of welded structural steel in seawater. The last paper is concerned with effects of cathodic protection on corrosion fatigue. It summarizes results of previous investigations by other workers.

This is an excellent symposium. The roles of chemistry, mechanics, materials, and metallurgy in the study of corrosion fatigue are emphasized. The reviewer recommends the book even though

some of the information will be outdated by additional findings in a relatively short time.

H. Saunders
1 Arcadian Drive
Scotia, NY 12302

BURIED STRUCTURES, STATIC AND DYNAMIC STRENGTH

P.S. Bulson
Chapman and Hall/Methuen, Inc.
New York, NY
0-412-21560-8
1985, 227 pages, $42.50

This book combines theory, experimental data, and practical design considerations for buried structures. The author does a commendable job of summarizing theory and existing data on the phenomena of soil-structure interaction around buried structures. He has drawn on his considerable experience over the past three decades to put together a text that should be useful to both designers and researchers.

There is an especially good summary of the general principles of soil arching for static loads. However, properties given in the section on cohesive soils are for drained conditions; these conditions should both be used for dynamic loads. The chapters on thick- and thin-walled pipes, noncircular pipes, closed cylinders, and shells under static loads are of value, as is an excellent summary of experimental data and practical considerations for designs.

The major shortcoming is in the treatment of structures subjected to dynamic loads. The guidelines given do not include dynamic soil-structure interaction (SSI) effects, probably because no significant structural damage occurred in any of the tests that were reviewed. More recent data from dynamic tests on shallow-buried structures indicate a significant reduction in interface loads as a result of SSI at burial depths as shallow as 20 percent of the roof span.

The section on the use of backpacking to reduce dynamic loads has several drawbacks that are not pointed out in the text. For example, the backpacking material will generally degrade or fill with water or soil over a period of time and no longer be effective. Also, backpacking will not help in a repeated loading because it is already in a locking state. A better suggestion than backpacking is to backfill with a material of high-shear strength and to design for larger ductilities so that SSI will protect the structure from excessive loads.

Chapter 7 contains an interesting discussion of design philosophy for buried structures. However, the author's recommendation of a ductility of 3 as moderate damage for underground blast shelters is too conservative. Cracks in typical reinforced concrete structures can barely be detected at a ductility of 3, which is very light damage at worst. Ductilities of 10 to 20 are more representative of moderate damage in reinforced concrete blast shelters. Much larger ductilities could be allowed in metal blast shelters.

The author's recommendation to use peak overpressure and a dynamic load factor (DLF) of 2 for elastic design of buried structures is also too conservative. For the relatively low peak overpressures and burial depths discussed, a rise time to peak pressure as well as some decrease in peak overpressure will occur at the roof interface. Therefore, a DLF equal to 1 for elastic designs is more reasonable for long duration loads -- perhaps less than 1 for relatively short load durations.

Overall, the book is an excellent reference on soil-arching phenomena as they relate to buried structures. It should be helpful to designers, especially those working with static loads on buried pipes and tunnels. The only shortcoming is in the treatment of dynamic loads and structural design for buried blast shelters. This is probably due to a lack of data from buried structures damaged in dynamic tests.

S.A. Kiger
USAE Waterways Experiment Station
P.O. Box 631
Vicksburg, MS 39180-0631

MECHANICAL VIBRATIONS WITH APPLICATIONS

A.C. Walshaw
Ellis Horwood, Ltd.
1984, 197 pages, $34.95

This book satisfies the aim set forth by the author at the outset: to provide students in the early stages of degree and diploma courses with a gradual and straightforward approach to the subject of mechanical vibrations. It will be useful at the introductory level for students and practical engineers. For this intended purpose, the topics covered are complete, except that a brief introduction to such modern computational

methods as numerical integration procedures and transfer matrix methods would have been desirable. In general, the book is easy to read and understandable. The extensive use of vector diagrams should lead to a better understanding by the reader of the component forces involved in mechanical vibrations. The graphic illustrations are well presented and easy to follow. A useful and novel aspect of the book is that it suggests many simple experimental setups for observing various vibration phenomena. Working through these experiments would be an interesting way to learn the subject for those studying vibrations for the first time.

T.S. Sankar
Concordia University
Montreal, Canada

SHORT COURSES

MAY

MACHINERY DIAGNOSTICS

Dates: May 5-9, 1986
Place: Carson City, Nevada
Dates: June 16-20, 1986
Place: Carson City, Nevada
Dates: June 24-27, 1986
Place: Denver, Colorado
Objective: This seminar instructs rotating machinery users on transducer fundamentals, the use of basic diagnostic techniques, and interpreting industry-accepted vibration data formats to diagnose common rotating machinery malfunctions. The seminar includes class demonstrations, case histories, and a hands-on workshop that allows participants to diagnose malfunctions on demonstrator rotor systems.

Contact: Bently Nevada's Customer Information Center, P.O. Box 157, Minden, NV 89437 800-227-5514, Ext. 9682.

VIBRATION AND SHOCK SURVIVABILITY, TESTING, MEASUREMENT, ANALYSIS, AND CALIBRATION

Dates: May 12-16, 1986
Place: Detroit, Michigan
Dates: June 2-6, 1986
Place: Santa Barbara, California
Dates: August 18-22, 1986
Place: Santa Barbara, California
Dates: October 6-10, 1986
Place: Boston, Massachusetts
Dates: November 3-7, 1986
Place: Orlando, Florida
Objective: Topics to be covered are resonance and fragility phenomena, and environmental vibration and shock measurement and analysis; also vibration and shock environmental testing to prove survivability. This course will concentrate upon equipments and techniques, rather than upon mathematics and theory.

Contact: Wayne Tustin, 22 East Los Olivos Street, Santa Barbara, CA 93105 -(805) 682-7171.

ROTATING MACHINERY VIBRATIONS

Dates: May 19-21, 1986
Place: Orlando, Florida
Objective: This course provides participants with an understanding of the principles and practices of rotating machinery vibrations and the application of these principles to practical problems. Some of the topics to be discussed are: theory of applied vibration engineering applied to rotating machinery; vibrational stresses and component fatigue; engineering instrumentation measurements; test data acquisition and diagnosis; fundamentals of rotor dynamics theory; bearing static and dynamic properties; system analysis; blading analysis; life estimation; practical rotor blading-bearing dynamics examples and case histories; rotor balancing theory; balancing of rotors in bearings; rotor signature analysis and diagnosis; and rotor-bearing failure prevention.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, Il 60514 - (312) 654-2254.

APPLIED VIBRATION ENGINEERING

Dates: May 19-21, 1986
Place: Orlando, Florida
Objective: This intensive course is designed for specialists, engineers and scientists involved with design against vibration or solving of existing vibration problems. This course provides participants with an understanding of the principles of vibration and the application of these principles to practical problems of vibration reduction or isolation. Some of the topics to be discussed are: fundamentals of vibration engineering; component vibration stresses and fatigue; instrumentation and measurement engineering; test data acquisition and diagnosis; applied spectrum analysis techniques; spectral analysis techniques for preventive maintenance; signal analysis for machinery diagnostics; random vibrations and processes; spectral density functions; modal analysis using graphic CRT display; damping and stiffness techniques for vibration control; sensor techniques for machinery diagnostics; transient response concepts and test procedures; field application of modal analysis for large systems; several sessions on

case histories in vibration engineering; applied vibration engineering state-of-the-art.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

VIBRATION DAMPING TECHNOLOGY
Dates: May 19-23, 1986
Place: Reno, Nevada
Dates: July 14-17, 1986
Place: Montreal, Canada
Dates: September 15-19, 1986
Place: Dayton, Ohio
Dates: January, 1987
Place: Clearwater, Florida
Objective: Basics of theory and application of viscoelastic and other damping techniques for vibration control. The courses will concentrate on behavior of damping materials and their effect on response of damped systems, linear and nonlinear, and emphasize learning through small group exercises. Attendance will be strictly limited to ensure individual attention.

Contact: David I. Jones, Damping Technology Information Services, Box 565, Centerville Branch USPO, Dayton, OH 45459-9998 - (513) 434-6893.

MACHINERY MONITORING
Dates: May 20-22, 1986
Place: Chicago, Illinois
Dates: June 10-12, 1986
Place: Anaheim, California
Objective: The seminar focuses on the principles of vibration measurement for rotating machinery monitoring. Subjects covered in the seminar include troubleshooting, calibration and maintenance of monitoring systems, and the applications and installation of displacement, velocity, and acceleration transducers.

Contact: Bently Nevada's Customer Information Center, P.O. Box 157, Minden, NV 89437 -800-227-5514, Ext. 9682.

JUNE

VIBRATION CONTROL
Dates: June 9-13, 1986
Place: San Diego, CA
Objective: Participants in this course should leave with an understanding of the options available for vibration control, including general design considerations and such control techniques as isolation and damping. Lectures provide a sound review of vibration theory and develop the principles of vibration isolation and damping as they apply to particular design problems. Examples and case histories are used to illustrate design approaches; participants can solve problems during workshops.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

DYNAMIC BALANCING
Dates: June 18-19, 1986
Place: Columbus, Ohio
Objective: Balancing experts will contribute a series of lectures on field balancing and balancing machines. Subjects include: field balancing methods; single, two and multi-plane balancing techniques; balancing tolerances and correction methods. The latest in-place balancing techniques will be demonstrated and used in the workshops. Balancing machines equipped with microprocessor instrumentation will also be demonstrated in the workshop sessions, where each student will be involved in hands-on problem-solving using actual armatures, pump impellers, turbine wheels, etc., with emphasis on reducing costs and improving quality in balancing operations.

Contact: R.E. Ellis, IRD Mechanalysis Inc., 6150 Huntley Road, Columbus, OH 43229 -(614) 885-5376.

JULY

FLOW-INDUCED OSCILLATIONS IN ENGINEERING SYSTEMS
Dates: July 1-2, 1986
Place: Bethlehem, Pennsylvania
Objective: The aim of this course is to provide the practicing engineer with a means of identification and assessment of the crucial flow mechanisms and flow-structure interactions leading to vibration and noise. Throughout the course, emphasis will be given to physical and practical interpretation of the common features of problems occurring in mechanical-, aerospace-, hydraulic-, and wind-engineering areas. The course will concentrate on the physical principles of identification, analysis, and attenuation (or cure) of oscillations, followed by

practical case studies, during which the instructor will cover examples from a variety of applications.

Contact: Dr. James Brown, Lehigh Director of Continuing Education, Office of Continuing Education, 219 Warren Square, Lehigh University, Bethlehem, PA 18015 - (215) 861-3934.

FINITE ELEMENTS IN MECHANICAL AND STRUCTURAL DESIGN A: LINEAR STATIC ANALYSIS

Dates: July 14-18, 1986
Place: Ann Arbor, Michigan
Objective: Presents energy formulation and modeling concepts. For engineers requiring stress, strain and displacement information. Attendees use personal computers to develop models of several problems and use MSC/-NASTRAN in laboratory sessions. No previous finite element experience is required.

Contact: William J. Anderson, Engineering Summer Conferences, 200 Chrysler Center, North Campus, The University of Michigan, Ann Arbor, MI 48109 - (313) 764-8490

MODAL TESTING OF MACHINES AND STRUCTURES

Dates: July 14-18, 1986
Place: Rindge, New Hampshire
Objective: Vibration testing and analysis associated with machines and structures will be discussed in detail. Practical examples will be given to illustrate important concepts. Theory and test philosophy of modal techniques, methods for mobility measurements, methods for analyzing mobility data, mathematical modeling from mobility data, and applications of modal test results will be presented.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

ROTOR DYNAMICS

Dates: July 14-18, 1986
Place: Rindge, New Hampshire
Objective: The role of rotor/bearing technology in the design, development and diagnostics of industrial machinery will be elaborated. The fundamentals of rotor dynamics; fluid-film bearings; and measurement, analytical, and computational techniques will be presented. The computation and measurement of critical speeds vibration response, and stability of rotor/bearing systems will be discussed in detail. Finite elements and transfer matrix modeling will be related to computation on mainframe computers, minicomputers, and microprocessors. Modeling and computation of transient rotor behavior and nonlinear fluid-film bearing behavior will be described. Sessions will be devoted to flexible rotor balancing including turbogenerator rotors, bow behavior, squeeze-film dampers for turbomachinery, advanced concepts in troubleshooting and instrumentation, and case histories involving the power and petrochemical industries.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

ADVANCED TECHNIQUES FOR NOISE CONTROL

Dates: July 17-19, 1986
Place: Cambridge, Massachusetts
Objective: Among the topics to be covered are modern instrumentation for noise control, modal analysis, sound *intensity* applications, active techniques for noise control, structural and vibration transmission, and airport noise and monitoring systems.

Contact: Institute of Noise Control Engineering, P.O. Box 3206 Arlington Branch, Poughkeepsie, NY 12603.

FINITE ELEMENTS IN MECHANICAL AND STRUCTURAL DESIGN B: DYNAMIC AND NONLINEAR ANALYSIS

Dates: July 21-25, 1986
Place: Ann Arbor, Michigan
Objective: Covers vibration, material nonlinearities, and geometric nonlinearities. Includes normal modes, transient response, Euler buckling, and heat conduction. Attendees use personal computers to develop models of several problems and use MSC/NASTRAN in laboratory sessions.

Contact: William J. Anderson, Engineering Summer Conferences, 200 Chrysler Center, North Campus, The University of Michigan, An Arbor, MI 48109 (313) 764-8490

FINITE ELEMENTS IN MECHANICAL AND STRUCTURAL DESIGN C: DESIGN SENSITIVITIES, CYCLIC SYMMETRY AND DMAP
Dates: July 28-August 1, 1986
Place: Ann Arbor, Michigan
Objective: Presents the use of design sensitivities and optimization (2 days), cyclic symmetry (1 day), DMAP programming (2 days). Attendees use MSC/NASTRAN to run sample problems in each topic. These methods greatly enhance the productivity and are now becoming widely used.

Contact: William J. Anderson, Engineering Summer Conferences, 200 Chrysler Center, North Campus, The University of Michigan, Ann Arbor, Michigan 48109 - (313) 764-8490.

AUGUST

DESIGN AND ANALYSIS OF ENGINEERING EXPERIMENTS
Dates: August 4-15, 1986
Place: Ann Arbor, Michigan
Objective: Recent developments in the field of testing, methods for designing experiments, interpretation of test data, and better utilization of the existing data. Design of experiments with a small number of test pieces or runs with high dispersion is emphasized. Obtaining maximum information from limited test data is stressed.

Contact: William J. Anderson, Engineering Summer Conferences, 200 Chrysler Center, North Campus, The University of Michigan, Ann Arbor, Michigan 48109 - (313) 764-8490.

MACHINERY VIBRATION ANALYSIS I
Dates: August 19-22, 1986
Place: New Orleans, Louisiana
Dates: November 11-14, 1986
Place: Chicago, Illinois
Objective: This course emphasizes the role of vibrations in mechanical equipment instrumentation for vibration measurement, techniques for vibration analysis and control, and vibration correction and criteria. Examples and case histories from actual vibration problems in the petroleum, process, chemical, power, paper, and pharmaceutical industries are used to illustrate techniques. Participants have the opportunity to become familiar with these techniques during the workshops. Lecture topics include: spectrum, time domain, modal, and orbital analysis; determination of natural frequency, resonance, and critical speed; vibration analysis of specific mechanical components, equipment, and equipment trains; identification of machine forces and frequencies; basic rotor dynamics including fluid-film bearing characteristics, instabilities, and response to mass unbalance; vibration correction including balancing; vibration control including isolation and damping of installed equipment; selection and use of instrumentation; equipment evaluation techniques; shop testing; and plant predictive and preventive maintenance. This course will be of interest to plant engineers and technicians who must identify and correct faults in machinery.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

VIBRATIONS OF RECIPROCATING MACHINERY
Dates: August 19-22, 1986
Place: New Orleans, Louisiana
Objective: This course on vibrations of reciprocating machinery includes piping and foundations. Equipment that will be addressed includes reciprocating compressors and pumps as well as engines of all types. Engineering problems will be discussed from the point of view of computation and measurement. Basic pulsation theory --including pulsations in reciprocating compressors and piping systems -- will be described. Acoustic resonance phenomena and digital acoustic simulation in piping will be reviewed. Calculations of piping vibration and stress will be illustrated with examples and case histories. Torsional vibrations of systems containing engines and pumps, compressors, and generators, including gearboxes and fluid drives, will be covered. Factors that should be considered during the design and analysis of foundations for engines and compressors will be discussed. Practical aspects of the vibrations of reciprocating machinery will be emphasized. Case histories and examples will be presented to illustrate techniques.

Contact: Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 West 55th Street, Suite 206, Clarendon Hills, IL 60514 -(312)654-2254.

NEWS BRIEFS: news on current and Future Shock and Vibration activities and events

INSTITUTE OF ENVIRONMENTAL SCIENCES
32ND ANNUAL TECHNICAL MEETING
Amfac Hotel and Resort, Dallas/Fort Worth Airport
May 5-9, 1986

During the week of May 5-9, 1986, the Annual Technical Meeting and Equipment Exposition of the Institute of Environmental Sciences (IES) will be held in Dallas/ Fort Worth, Texas. The theme, "Environmental Technology -- Coming of Age," acknowledges the growth and ultimate emergence of the IES and its Technical Divisions as leaders in our technical arenas.

The technical program has been designed to enhance the awareness regarding the interfaces between the IES disciplines and the IES community. For example, five sessions will have U.S. and European Co-Chairman. All international papers will be integrated by content within their appropriate technical session. In addition, there are four joint sessions: Design, Test and Evaluation/Computer Applications; Design Test and Evaluation/Contamination Control; Product Reliability/Computer Applications; Product Reliability/Design, Test and Evaluation.

The program features nine tutorials structured to provide basic and advanced training in contamination control, vibration and shock. The Equipment Exposition promises to be the most impressive in IES history with close to 200 exhibits. All IES technical committees and working groups will meet to plan future activities.

For further information contact: Institute of Environmental Sciences, 940 East Northwest Highway, Mount Prospect, IL 60056.

41ST MECHANICAL FAILURES PREVENTION GROUP SYMPOSIUM
Patuxent River, Maryland
October 28-30, 1986

The 41st meeting of the MFPG will be sponsored by the National Bureau of Standards, the Office of Naval Research, and the Army Materials and Mechanics Research Center. These symposia have become recognized as the outstanding forum for discussion of mechanical failure reduction as well as the development of methods to predict incipient failure. Their purpose is to aid communications among those involved with the reduction of mechanical failures through detection, diagnosis and prognosis (DD&P); durability evaluations; and the understanding of failure mechanisms. The theme of the 41st meeting is: "DD&P of Rotating Machinery to Improve Reliability, Maintainability and Readiness through Application of New and Innovative Techniques."

Of particular interest is the use of vibration analysis for the detection of bearing and gear faults within gear boxes and engines. Long term goals of on-condition maintenance are of primary importance. The need to address this topic was focused by the recent widespread and successful applications of new DD&P techniques by both the Department of Defense and industry.

For information write to: T. Robert Shives, A113 Materials Bldg., National Bureau of Standards, Gaithersburg, Maryland 20899.

ABSTRACTS FROM THE CURRENT LITERATURE

ABSTRACT CONTENTS

AVAILABILITY OF PUBLICATIONS ABSTRACTED

None of the publications are available at SVIC or at the Vibration Institute, except those generated by either organization.

Periodical articles, society papers, and papers presented at conferences may be obtained at the Engineering Societies Library, 345 East 47th Street, New York, NY 10017; or Library of Congress, Washington, D.C., when not available in local or company libraries.

Government reports may be purchased from National Technical Information Service, Springfield, VA 22161. They are identified at the end of bibliographic citation by an NTIS order number with prefixes such as AD, N, NTIS, PB, DE, NUREG, DOE, and ERATL.

Ph.D. dissertations are identified by a DA order number and are available from University Microfilms International, Dissertation Copies, P.O. Box 1764, Ann Arbor, MI 48108.

U.S. patents and patent applications may be ordered by patent or patent application number from Commissioner of Patents, Washington, D.C. 20231.

Chinese publications, identified by a CSTA order number, are available in Chinese or English translation from International Information Service, Ltd., P.O. Box 24683, ABD Post Office, Hong Kong.

Institution of Mechanical Engineers publications are available in U.S.: SAE Customer Service, Dept. 676, 400 Commonwealth Drive, Warrendale, PA 15096, by quoting the SAE-MEP number.

When ordering, the pertinent order number should always be included, <u>not</u> the DIGEST abstract number.

A List of Periodicals Scanned is published in issues, 1, 6, and 12.

MECHANICAL SYSTEMS

ROTATING MACHINES

86-743
Experience with a New Approach to Rotor Aeroelasticity
M.H. Patel, G.T.S. Done
The City University, London, England
Vertica, 9 (3), pp 285-294 (1985) 9 figs, 9 tables, 5 refs

KEY WORDS: Helicopters, Rotors, Computer programs, Aeroelasticity

Experience with an alternative procedure for computing the aeroelastic stability of a helicopter rotor system is described. The method is aimed at generating the coefficients of the aeroelastic equations of motion automatically on the computer. The main objective of the current work is to validate the associated computer program using three practical examples. These examples are graded such that different aspects of the program are tested.

86-744
The Effect of Higher Harmonic Control (HHC) on a Four-Bladed Hingeless Model Rotor
G. Lehmann
Institut fur Flugmechanik, Braunschweig, Fed. Rep. of Germany
Vertica, 9 (3), pp 273-284 (1985) 21 figs, 6 refs

KEY WORDS: Rotors, Active vibration control, Helicopter vibration

A four-bladed hingeless rotor system was used for application of higher harmonic control (HHC) inputs. With the objective of obtaining a better knowledge of the dynamic behavior of rotor forces and moments, theoretical and experimental investigations were conducted. Wind tunnel measurements in the DNW with the DFVLR rotor test rig included different advance ratios and trimmed flight conditions scaled down from the BO-105 helicopter. After a brief description of the test equipment, the sensor arrangement, the data acquisition and date reduction, the evaluation of the reference data is described.

86-745
Stablilizing Subsynchoronous Resonance Using a Shunt Connected, Current Reference Power Converter
C. Chen
Ph.D. Thesis, Purdue, Univ., 174 pp (1984) DA8507667

KEY WORDS: Steam turbines, Subsynchronous vibration, Vibration control

In power systems containing series capacitor compensated transmission lines, the natural frequencies of the turbine prime movers in stream turbogenerators may become self excited due to an unstable interaction between the transmission network and the torsional modes of the steam turbine. Such instabilities fall into the general category of subsynchronous resonance (SSR). The research introduces a new countermeasure to SSR using a controlled, shunt connected static power converter. This method involved the measurement of the transmission system currents which are subsequently transformed into a synchronously rotating frame of reference.

86-746
Damping Applications in Turbine Engines
R.L. Jay, D.W. Burns
General Motors Corp., Indianapolis, IN
Vib. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, AD-A152 547, pH-1-H-24, AD-P004 692/0/GAR

KEY WORDS: Turbine engines, Vibration damping, Design Techniques

An evaluation of the application of damping treatments to turbomachinery rotating and static components based on measured response characteristics of compressor and turbine stages was performed. In the evaluation, data from a shrouded fan stage, an integral turbine stage, and two stator vane assemblies were used. From the data the contributions due to material damping, interface damping and aerodynamic damping comprising the total system damping were obtained. Based on these identifications a basis for the application of damping treatments which would be effective in controlling resonant response amplitudes is established.

86-747
Modal Response of a Disk to a Moving Concentrated Harmonic Force
Y. Honda, H. Matsuhisa, S. Sato

Kyoto University, Kyoto, Japan
J. Sound Vib., 102 (4), pp 457-472 (Oct 22, 1985) 8 figs, 8 refs

KEY WORDS: Disks, Modal analysis, Moving loads, Harmonic excitation

The steady state response of a stationary disk to a concentrated harmonic force moving in a concentric circular path at a constant velocity is analyzed. Formulation of the response with structural damping is derived as an eigenfunction series. The modal response is discussed in detail, with emphasis on the vibratory modes. The effect of imperfection in the axial symmetry is also discussed.

86-748
Punch Press Mechanical Clutch Engagement Noise and Noise Reduction
L.L. Koss, W. Kowalczyk
Monash University, Clayton, Victoria, Australia
J. Sound Vib., 102 (4), pp 527-549 (Oct 22, 1985) 10 figs, 14 tables, 12 refs

KEY WORDS: Presses, Noise reduction, Clutches

Results of an analysis of noise radiated during mechanical clutch key engagement for a 170-kN, a 230-kN, and a 300-kN punch press are presented. Experiments undertaken to reduce the noise radiated by replacement of the all steel key with a composite steel-Nylatron key indicate reductions of up to 6dB(A) can be achieved at an operator's position.

RICIPROCATING MACHINES

86-749
Noise and Efficiency Analysis of Axial Piston Units (Gerausch-und Wirkungsgradanalyse an Axialkolbeneinheiten)
R. Bavendiek
Konstruktion, 37 (6), pp 243-249 (June 1985) 6 figs, 4 refs (in German)

KEY WORDS: Reciprocating machinery, Noise generation

A test stand is described for a simultaneous determination of noise emission and efficiency of axial piston machinery. After expounding the A-acoustic power level, the volumetric, the hydraulic-mechanic and the degree of total effect as the suitable characteristics, a description of the test stand, the fully automatic computer-aided process control, and data recordings and processings is discussed. The measure characteristic fields for the degree of total effect and the acoustic power level are given.

POWER TRANSMISSION SYSTEMS

86-750
Variable-Frequency Drives Multiply Torsional Vibration Problems
F.H. Wolff, A.J. Molnar
Engrg. Analytical Dynamics Corp.
Power, pp 83-85 (June 1985) 9 figs, 3 refs

KEY WORDS: Variable speed drives, Torsional vibrations

Analysis of torsional dynamics early in the drive design stage prevent a wide range of torsional excitation frequencies that may present problems later.

METAL WORKING AND FORMING

86-751
Stability Analysis of Chatter Vibration in Turning Processes
M. Rahman, Y. Ito
National University of Singapore, Singapore
J. Sound Vib., 102 (4), pp 515-525 (Oct 22, 1985) 8 figs, 3 tables, 9 refs

KEY WORDS: Machining, Chatter

Most turning operations are carried out with use of three-jaw chucks. The position of the jaws with respect to the direction of the cutting force causes a variation in the mass, damping coefficient and stiffness of the workpiece-chuck-spindle system, the variations being larger when the cutting force is acting against a jaw and smaller when the cutting force is acting along a jaw. These factors are usually considered to be constant when carrying out a stability analysis of self-excited chatter appearing in a turning process and, in consequence, the experimental results so far presented are sometimes found not to agree with the theoretical ones.

86-752
Noise Control in Materials Handling Systems
L.F. Yerges
S/V, Sound Vib., 19 (7), pp 16-21 (July 1985) 1 fig, 5 tables

KEY WORDS: Materials handling equipment, Noise reduction

A wealth of information on the physics of sound and the mechanics of vibrating bodies is available to the engineer; and many excellent books and references on noise and vibration control are available. In this article only the information necessary for any competent engineer to design noise out of equipment or to control the unavoidable noise and vibration generated by such equipment and its operation are discussed.

STRUCTURAL SYSTEMS

BUILDINGS

86-753
Lateral-Torsional Motion of Tall Buildings to Wind Loads
A. Kareem
Univ. of Houston, Houston, TX
ASCE J. Struc. Engrg., 111 (11), pp 2479-2496 (Nov 1985) 5 figs, 3 tables, 28 refs

KEY WORDS: Multistory buildings, Wind-induced excitation, Torsional response

The lateral-torsional motion of tall buildings is investigated. For a square cross-section building, expressions for the alongwind, acrosswind and torsional loading are developed through the use of spatio-temporal fluctuations in the pressure field around the building. A simplified formulation is used to represent the dynamic behavior of torsionally coupled buildings by considering a class of buildings in which all floors have the same geometry in plan, the eccentricities between the elastic and mass centers are the same for all stories, and the ratio of the story stiffness in lateral directions is about the same for all stories. Methods of random vibration theory are used to estimate the rms and peak values of various components of response.

86-754
Structural Performance and Wind Speed-Damage Correlation in Hurricane Alicia
A. Kareem
Univ. of Houston, Houston, TX
ASCE J. Struc. Engrg., 111 (12), pp 2596-2610 (Dec 1985) 14 figs, 1 table, 13 refs

KEY WORDS: Buildings, Wind-induced excitation, Design techniques

The performance of buildings and other constructed facilities in the Houston-Galveston area during Hurricane Alicia on August 18, 1983 are described. Records obtained from 17 anemometer sites in the Houston-Galveston area provide estimates of the fastest mile speed at 10 m above ground in open terrain. The wind speed estimates at various locations are compared with codes and standards for wind speed design values for constructed facilities.

86-755
Wind Induced Lateral-Torsional Motion of Buildings
A. Tallin, B. Ellingwood
Polytechnic Inst. of New York, Brooklyn, NY
ASCE J. Struc. Engrg., 111 (10) pp 2197-2213 (Oct 1985) 6 figs, 5 tables, 16 refs

KEY WORDS: Buildings, Wind-induced excitation, Torsional response, Lateral response

Fluctuating wind forces on tall buildings can cause excessive building motion that may be disturbing to the occupants. A method to related dynamic alongwind, acrosswind, and torsional forces acting on square isolated buildings to building accelerations is developed using random vibration theory. Wind tunnel test data are analyzed to determine the spectra of force components and correlations among the different components of force.

86-756
Equivalent Loading Due to Airplane Impact Taking into Account the Non-Linearities of Impacted Reinforced Concrete Buildings
J.F. Chadmail, N.J. Krutzik, T. DuBois

Engineering System Internation GmbH, Eschborn, Fed. Rep. Germany
Nucl. Engrg. Des., 85 (1), pp 47-57 (Feb 1985) 21 figs, 2 tables, 16 refs

KEY WORDS: Buildings, Reinforced concrete, Nuclear power plants, Impact response, Crash research (aircraft)

The airplane impact loading condition applied to a nuclear power plant building usually leads to very large excitations locally around the impact point and in the overall structure. The object of the paper is to present a numerical method of determining the dynamic response at characteristic points of the building taking into account the nonlinear behavior of locally impacted cracked damaged concrete. The method is based on the determination of a verified load function which, applied to linear elastic model of the structure, leads to the same response of the building (far from the impact point) as that due to the rigid load function impact force applied to a more realistic nonlinear model of the reinforced concrete building. This procedure avoids long and costly nonlinear time integration of a full structural model.

86-757
Comparison of Results of Soil-Structure Interaction Analyses Based on Time and Frequency Domain Approaches with Emphasis on Treatment of Damping
A. Gantayat, H. Kamil, N.J. Krutzik
Engineering Decision Analysis Company, Inc., Palo Alto, CA
Nucl. Engrg. Des., 85 (1), pp 39-46 (Feb 1985) 6 figs, 3 refs

KEY WORDS: Buildings, Nuclear power plants, Soil structure interaction, Impact response, Crash research (aircraft)

Comparison of results of soil-structure interaction analyses of the reactor building of a nuclear power plant using different analytical approaches and solution procedures is presented. The emphasis of the comparison was on the treatment of damping in these different approaches and procedures. An axisymmetric model of the reactor building was employed. The analyses were performed for the aircraft impact loadings. Two different locations were used for these loadings.

86-758
Performance of Eigensolvers in Modal Analyses of Nuclear Plant Building Structures
K.R. Leimbach, V.H. Engelke, N.J. Krutzik
Kraftwerk Union AG, Offenbach/Main, Fed. Rep. Germany
Nucl. Engrg. Des., 85 (1), pp 31-37 (Feb 1985) 1 fig, 4 tables, 9 refs

KEY WORDS: Buildings, Nuclear power plants, Modal analysis

The modal time history analysis of nuclear plant building structures subjected to dynamic excitations requires the computation of free vibration modes and frequencies. The models are extremely complex and are characterized by a large number of equations, a large half-bandwidth and a large number of modes and frequencies to be computed. In the present paper the computations are carried out with different eigensolution routines on a number of large size nuclear plant structural models. A number of performance characteristics are recorded to offer some basis of comparison for the user of such algorithms.

86-759
Optimum Building Design for Forced-Mode Compliance
T. Nakamura, I. Takewaki
Kyoto Univ., Kyoto, Japan
ASCE J. Engrg. Mech., 111 (9), pp 1159-1174 (Sept 1985) 8 figs, 2 tables, 10 refs

KEY WORDS: Buildings, Ground motion, Seismic design

A new dynamic system response quantity, referred to as forced-mode compliance, is introduced for the forced steady-state vibration of a shear building model subjected to a harmonic ground motion. An optimum design problem subject to the constraints on forced-mode compliance, on fundamental natural frequency and on minimum stiffnesses is formulated and the necessary and sufficient conditions for global optimality are derived.

86-760
System Identification of Hysteretic Structures
A.O. Cifuentes
Ph.D. Thesis, California Inst. of Technology, 166 pp (1985) DA8508457

KEY WORDS: Buildings, Reinforced concrete, System identification techniques, Seismic response, Hysteretic damping

The earthquake response of hysteretic structures subjected to strong ground acceleration is studied. Several earthquake records corresponding to different instrumented buildings are analyzed. Based on these observations, a new model for the dynamic behavior of reinforced concrete buildings is proposed. In addition, a suitable system identification algorithm to be used with this new model is introduced.

86-761
Active Control of Seismic-Excited Buildings
B. Samali, J.N. Yang, S.C. Liu
George Washington Univ., Washington, D.C.
ASCE J. Struc. Engrg., 111 (10), pp 2165-2180 (Oct 1985) 14 figs, 35 refs

KEY WORDS: Multistory buildings, Seismic response, Active control

An investigation is made of the possible application of both the active tendon and active mass damper control systems to buildings excited by strong earthquakes. The effectiveness of both active control systems as measured by the reduction of coupled lateral-torsional motions of buildings is studied. The earthquake ground acceleration is modeled as a uniformly modulated non-stationary random process.

86-762
Simplified Earthquake Analysis of Multistory Structures with Foundation Uplift
S.C.-S. Yim, A.K. Chopra
Exxon Production Research Co., Houston, TX
ASCE J. Struc. Engrg., 111 (12), pp 2708-2731 (Dec 1985) 10 figs, 12 refs

KEY WORDS: Multistory buildings, Seismic response, Base excitation

A simplified analysis procedure is developed to consider the beneficial effects of foundation-mat uplift in computing the earthquake response of multistory structures. This analysis procedure is presented for structures attached to a rigid foundation mat which is supported on flexible foundation soil modeled as two spring-damper elements. Winkler foundation with distributed spring-damper elements, or a viscoelastic half space.

TOWERS

86-763
Investigation of Wind Effects on Tall Guyed Tower
R.T. Nakamoto, A.N.L. Chiu
Naval Civ. Engrg. Lab., Port Hueneme, CA
ASCE J. Struc. Engrg., 111 (11), pp 2320-2332 (Nov 1985) 6 figs, 3 tables, 19 refs

KEY WORDS: Towers, Guyed structures, Wind-induced excitation, Experimental data

Full-scale wind velocity and structural response data from a tall guyed tower have been analyzed to obtain information concerning wind characteristics and dynamic response. Anemometers and accelerometers were installed at five stations along the height of a tower, and orthogonal components of wind velocities and tower accelerations were recorded.

86-764
Inelastic Response of Tubular Steel Offshore Towers
E.P. Popov, S.A. Mahin, R.W. Clough
Univ. of California, Berkeley, CA
ASCE J. Struc. Engrg., 111 (10), pp 2240-2258 (Oct 1985) 23 figs, 1 table, 27 refs

KEY WORDS: Towers, Offshore structures, Seismic excitation, Testing techniques

Three alternative experimental methods for subjecting structural models of steel offshore towers to severe inelastic lateral loadings simulating seismic effects are described. There pertain to either pseudo-static or pseudo-dynamic methods of loading, or to experiments performed using a shaking table. These methods are evaluated and test results are highlighted to provide insight into the inelastic cyclic behavior of this type of structure.

FOUNDATIONS

86-765
Influence of Foundation Flexibility on Soil-Structure Interaction
H.R. Riggs, G. Waas

Hochtief AG, Frankfurt am Main, W. Germany
Earthquake Engrg. Struc. Dynam., 13 (5), pp 597-615 (Sept/Oct 1985) 14 figs, 1 table, 9 refs

KEY WORDS: Soil-structure interaction, Nuclear reactors, Flexible foundations

The effect of the base mat flexibility on seismic soil-structure interaction is studied for an axisymmetric reactor building on a soft and a stiff soil. The dynamic response of a massless flexible circular plate with two rigid concentric walls, through which the plate is loaded, is analyzed.

86-766
Transmitting Boundaries and Seismic Response
A.T.F. Chen
U.S. Geological Survey, Menlo Park, CA
ASCE J. Geotech. Engrg., 111 (2), pp 174-192 (Feb 1985) 8 figs, 13 refs

KEY WORDS: Seismic response, Soils

A parametric study of the seismic response of a chosen site was conducted to demonstrate the obvious inconsistencies in computed ground response as a result of different assumptions made on the transmitting boundary for the site. The cause of these inconsistencies in computed response is the departure from the ideal assumption that the solid deposit below the transmitting boundary is a linear elastic and homogeneous half-space.

86-767
Spring Stiffnesses for Beam-Column Analysis of Soil-Structure Interaction Problems
R.L. Hall
Army Engineer Waterways Experiment Station, Vicksburg, MS
Rept. No. WES/TR/K-85-2, 128 pp (July 1985) AD-A158 072/9/GAR

KEY WORDS: Foundations, Beam-columns, Soil-structure interaction

The study documented in this report provides a simple means of combining a two-dimensional foundation with a beam-column structure for use in preliminary design and analysis. The report demonstrates that a foundation can be investigated and formed independently of the structural beam-column matrix. Two procedures for developing and interface matrix, which represents a linear elastic semi-infinite half plane, are presented.

86-768
Inverted Shear Modulus from Wave-Induced Soil Motion
L. Figueroa, T. Yamamoto, T. Nagai
Univ. of Miami, Coral Gables, FL
ASCE J. Geotech. Engrg., 111 (1), pp 115-132 (Jan 1985) 10 figs, 22 refs

KEY WORDS: Soils, Shear modulus, Damping coefficients, Cyclic loading, Measurement techniques

A previously developed technique, used mainly in seismology and geophysics, has been adopted to determine the shear modulus from soil displacements measured during wave tank experiments. This iterative inversion technique allowed the determination of the shear modulus and Coulomb specific loss (damping) with depth within a bentonite clay profile. It also allowed the observation of both the modulus reduction and damping curves for large shear strain amplitudes (up to 7%) for the first time.

86-769
Cyclic Behavior of Pavement Base Materials
M. McVay, Y. Taesiri
Univ. of Florida, Gainesville, FL
ASCE J. Geotech. Engrg., 111 (1), pp 1-17 (Jan 1985) 13 figs, 19 refs

KEY WORDS: Sand, Pavements, Soil-structure interaction, Moving loads, Cyclic loading

The influence of stress path on the stress-strain behavior of a Florida sand subject to repetitive moving wheel loads is investigated in the laboratory with conventional triaxial equipment. A conventional resilient modulus test with only cyclic varying compressive loads and a moving wheel stress path involving both extension and compressive loads determined from an elastic solution were examined at different initial confining pressures.

UNDERGROUND STRUCTURES

86-770
Dynamic Behaviour of Tunnels Under Impact Loads
J. Lysmer, P. Arnold, M. Jakub, N.J. Krutzik
Univ. of California, Berkeley, CA
Nucl. Engrg. Des., 85 (1), pp 65-69 (Feb 1985) 10 figs, 3 refs

KEY WORDS: Tunnels, Impact response, Crash research (aircraft)

Safety related structures of a nuclear power plant are often required to withstand the effects of an aircraft impact load. Underground tunnels, carrying cables and pipes between buildings, also being to this class of structures. For the design of components located inside the tunnels the response of the structure of the connection points of the components must be known. Acceleration response spectra and relative displacements are of major interest. Using finite element techniques in order to idealize the tunnel and the surrounding soil, the effects of the various parameters on the dynamic response of the tunnels are investigated.

HARBORS AND DAMS

86-771
Dynamic Analysis of Short-Length Gravity Dams
A.A. Rashed, W.D. Iwan
Johns Hopkins Univ., Baltimore, MD
ASCE J. Engrg. Mech., 111 (8), pp 1067-1083 (Aug 1985) 7 figs, 1 table, 19 refs

KEY WORDS: Dams, Natural frequencies, Mode shapes, Raleigh-Ritz method

A simplified and economical procedure is developed to analyze the dynamic behavior of short-length gravity dams. The analysis is based on the Rayleigh-Ritz method and an idealized dam-reservoir geometry. The substructure concept is used, in which the dam is modeled as a thick plate and the water in the reservoir is treated as a continuum. The model accounts for dam-reservoir interaction, water compressibility, and flexibility of the reservoir floor and sides. The natural frequencies and mode shapes of the dam are obtained through a free vibration analysis, and the three-dimensional effects on these properties are illustrated.

86-772
Finite Element Modeling of Infinite Reservoirs
S.K. Sharan
Laurentian Univ., Sudbury, Ontario, Canada
ASCE J. Engrg. Mech., 111 (12), pp 1457-1469 (Dec 1985) 8 figs, 20 refs

KEY WORDS: Dams, Hydrodynamic excitation, Finite Element technique

A technique is developed to model the effects of radiation damping in the finite element analysis of hydrodynamic pressures on dams subjected to a harmonic horizontal ground motion. The effectiveness of the proposed method is demonstrated by analyzing several cases.

86-773
Hydrodynamic Pressure on a Dam During Earthquakes
A. Chakrabarti, V.N. Nalini
Indian Inst. of Science, Bangalore, India
ASCE J. Engrg. Mech., 111 (12), pp 1435-1439 (Dec 1985) 1 fig, 8 refs

KEY WORDS: Dams, Seismic response, Hydrodynamic excitation

A straightforward analysis involving Fourier cosine transforms and the theory of Fourier series is presented for the approximate calculation of the hydrodynamic pressure exerted on the vertical upstream face of a dam due to constant earthquake ground acceleration. The analysis uses the Parseval relation on the Fourier coefficients of square integrable functions, and directly brings out the mathematical nature of the approximate theory involved.

86-774
Nonlinear Earthquake-Response Analysis of Earth Dams
A.-W. M. Elgamal
Ph.D. Thesis, Princeton Univ., 330 pp (1985) DA8505157

KEY WORDS: Dams, Seismic analysis, Hysteretic damping

A simplified cost-effective analytical-numerical procedure is developed for the nonlinear hysteretic seismic analysis of earth dams. This procedure can be utilized for the nonlinear dynamic response of soil (and/or structural)

systems. The procedure is based on a Galerkin formulation of the equations of motion in which the solution is expanded using basis functions defined over the spatial domain occupied by the dam or the soil system. The basis functions are selected to be the eigenmodes of the corresponding linear problem. Time histories of response are computed using time integration. A nonlinear elasto-plastic kinematic multi-yield surface, constitutive model for soil under dynamic loads is proposed.

86-775
Elasto-Plastic Earthquake Shear-Response of One-Dimensional Earth Dam Models
A-W.M. Elgamal, A.M. Abdel-Ghaffar, J.H. Prevost
Princeton Univ., Princeton, NJ
Earthquake Engrg. Struc. Dynam., 13 (5), pp 617-633 (Sept/Oct 1985) 14 figs, 30 refs

KEY WORDS: Dams, Seismic response, Nonlinear response

A simplified analysis procedure for the nonlinear hysteretic earthquake-response of earth dams is presented. The dam is modeled as a one-dimensional hysteretic shear-wedge subjected to base excitation. The hysteretic stress-strain behavior of the dam materials is modeled by using elasto-plastic constitutive equations based on multi-surface kinematic plasticity theory. The method is based on a Galerkin formulation of the equations of motion in which the solution is expanded using eigenmodes of the linearized problem defined over the spatial domain occupied by the dam.

ROADS AND TRACKS

86-776
Periodic Microslip Between a Rolling Wheel and a Corrugated Rail
S.L. Grassie, K.L. Johnson
Cambridge Univ., Cambridge, England
Wear, 101 (4), pp 291-309 (Feb 15, 1985) 9 figs, 18 refs

KEY WORDS: Track roughness, Rail-wheel interaction, Energy dissipation

Methods are presented for calculating the dissipation of frictional energy between a rolling wheel and a sinusoidally corrugated rail which is flexible in the vertical plane. In the absence of dynamic flexibility of the track in the plane of the contact it is found that the frictional dissipation is greatest when a wheel is on the ascending flank of a corrugation and that the amplitude of dissipation decreases continuously with corrugation wave-length.

CONSTRUCTION EQUIPMENT

86-777
The Simplified Dynamic Model, Measurement and Evaluation of Ride Vibration for the Combination Unit of Agricultural Hand Tractor and Trailer
Wu Qi-Ya, Su Qing-Za, Wang Jin-Wen, Fan Yong-Fa
Jiangsu Inst. of Technology, Zhenjiang, Jiangsu, China
Vehicle Syst. Dynam., 13 (6), pp 367-385 (1984) 13 figs, 20 refs

KEY WORDS: Tractors, Articulated vehicles, Road Roughness, Modal Synthesis, Ride dynamics

A mathematical model of four degree-of-freedom of a combination unit is developed, formulated by the modal synthesis technique. The spectral matrix of the acceleration response of the combination unit is derived on the basis of the model. The relationship between the spectral matrix and the road roughness spectrum is also given.

POWER PLANTS

86-778
Principles of Earthquake Design for Nuclear Power Plants in the FRG — A Critical Review and a Realistic Approach
M. Hintergräber, R. Wittmann
Kraftwerk Union AG, Erlangen, Fed. Rep. Germany
Nucl. Engrg. Des., 85 (1), pp 83-88 (Feb 1985) 1 fig, 1 table, 1 ref

KEY WORDS: Nuclear power plants, Seismic design

The principles of earthquake design for nuclear power plants in the FRG are recorded in the German nuclear safety standard KTA 2201.1. The regulations are based on US regulations which results at least in an overestimation of the earthquake risk in Germany. On the basis of this knowledge a group of German experts has drafted a new proposal for KTA 2201.1, including several basic modifications.

86-779
Dynamic Behavior of Boiling Water Reactors
J. March-Leuba
Ph.D. Thesis, Univ. of Tennessee, 295 pp (1984) DA8506902

KEY WORDS: Nuclear reactors, Dynamic stability

A study of the basic processes involved in boiling water nuclear reactor dynamics is presented. The main emphasis of this research has been placed on the physical interpretation of these processes. It is shown that this type of reactors has two regimes of operation: linear, during normal operation, and nonlinear, if they become unstable due to the thermohydraulic feedback. Both of these regimes are studied using low-order phpysical models.

86-780
Integration of Nondestructive Examination Reliability and Fracture Mechanics
S.R. Doctor, S.H. Bush, F.A. Simonen, T.T. Taylor
Pacific Northwest Laboratory, Richland, WA
Nucl. Engrg. Des., 86 (1), pp 21-30 (Apr 1985) 4 figs, 3 tables, 4 refs

KEY WORDS: Nuclear reactor components, Pipes, Nondestructive tests, Fracture properties

A program to determine the reliability of ultrasonic ISI performed on light-water reactor primary systems, using probabilistic fracture mechanics (FM) analysis to determine the impact of NDE unreliability on system safety, and to evaluate advanced ultrasonic techniques is reviewed. Emphasis is placed upon the results of a pipe inspection round robin, advanced technique evaluation, joint study with Westinghouse, qualification document, underclad crack detection sizing studies, and a FM analysis using the PRAISE code for studying inspection parameters.

86-781
Vibrations of Nuclear Fuel Assemblies: A Simplified Model
J. Planchard
Electricite de France, Clamart, France
Nucl. Engrg. Des., 86 (3), pp 383-391 (June 1985) 5 figs, 19 refs

KEY WORDS: Nuclear reactor components, Nuclear fuel elements, Fluid-structure interaction

The resonance frequencies of nuclear reactor cores is studied. The homogenized equations are obtained by representing the coupled cooling fluid-rod system as an equivalent continuous material. The homogenized dynamical equations are also derived and numerical procedures are presented.

86-782
Investigation of the Structural Behaviour of Nuclear Spent Fuel Reprocessing Plant Components Subjected to Dynamic Loads
J. Mischke, P. Leister, F.-O. Henkel
Deutsche Gesellschaft für Wiederaufarbeitung von Kernbrennstoffen mbH, Hannover, Fed. Rep. Germany
Nucl. Engrg. Des., 85 (2), pp 163-176 (1985) 16 figs, 1 table, 9 refs

KEY WORDS: Nuclear waste depositories, Nuclear fuel elements, Seismic response

In the planned reprocessing plant for spent nuclear fuel elements in Germany, components and systems which form a process-technical unit are integrated in a steel structure called a module. The stability and strength of two representative modules under dynamic loading due to earthquake are investigated.

VEHICLE SYSTEMS

GROUND VEHICLES

86-783
Dynamic Modal Analysis Improves Body Rigidity
J. Yamaguchi
Auto. Engrg. SAE, pp 81-84 (June 1985) 9 figs

KEY WORDS: Modal analysis, Automobiles

The body shell of a new compact car, stiffer in torsion and bending by ten percent and 19 per cent respectively than that of its predecessor, contributing to the car's marked improvement in NVH control as well as in handling characteristics, is described. The lower structure of the unitary body shell was designed and developed employing the dynamic modal analysis method.

86-784
Energy Dissipation Due to Vehicle/Track Interaction
J.E. Dzielski, J.K. Hedrick
Massachusetts Inst. of Technology, Cambridge, MA
Vehicle Syst. Dynam., 13 (6), pp 315-337 (1984) 14 figs, 4 tables, 10 refs

KEY WORDS: Rail-vehicle interaction, Energy dissipation, Rail-wheel interaction

The effects of track irregularities and wheel profile on the amount of energy dissipated in railroad freight vehicles is examined. A nonlinear computational model is used to determine the average dissipation in the vehicle suspension and the wheel/rail contact patches. This dissipation is a component of the total resistance force acting on the vehicle. Parametric results are presented showing the effects of track geometry, wheel profile, suspension design, and hunting on train resistance.

86-785
Critical Speed and Limit Speed in Phenomena of Lateral Instability on Railway Vehicles
A. Bonadero, A. Elia
Fiatt Ferroviaria Savigliano, Turin, Italy
Vehicle Syst. Dynam., 13 (6), pp 339-356 (1984) 13 figs, 9 refs

KEY WORDS: Railroad trains, Critical speeds, Hunting motion, Rail-wheel interaction

A comparison between theoretical calculations on dynamic lateral behavior of railway vehicles and experimental results shows quite a sizeable difference between the calculated critical speed and the actual speed at which side impact phenomena will repeatedly occur between wheel flange and rail (running speed limit), such impact speed being remarkably lower than calculated. Another typical experimental aspect is that the running speed limit will considerably vary for the same vehicle depending on the test track conditions. Such difference is usually attributed to alterations of the wheel-rail contact surfaces, only. This paper discusses some concurrent causes which may prove far from negligible, such as the effects of track defects, an amplification of the dynamic lateral displacement between wheel and rail on approaching the critical speed, the track mechanical properties, and in particular the track lateral rigidity.

86-786
Analysis Method of Head-on Vehicle Collision
A. Maslowstet, J. Krutul
Technical Univ. of Bialystok, Bialystok, Poland
Vehicle Syst. Dynam., 13 (6), pp 357-366 (1984) 7 figs, 4 refs

KEY WORDS: Collision research (automotive)

A method of analysis of vehicle head-on collision, based on the concept of dispersion of stress waves in rods upon axial impact, is presented. The mathematical model of collision studied here describes the vehicle behavior in collision in terms of a one-dimensional, nonhomogeneous, nonlinear partial differential equation. A procedure of model identification and some remarks concerning experimental data are discussed.

86-787
High Speed Stability for Rail Vehicles Considering Varying Conicity and Creep Coefficients
M. Nó, J.K. Hedrick
Centro de Estudios e Investigaciones Técnicas de Guipúzcoa, San Sebastián, Spain
Vehicle Syst. Dynam., 13 (6), pp 299-313 (1984) 11 figs, 3 tables, 10 refs

KEY WORDS: Railroad trains, Critical speeds, Hunting motion

The critical hunting speed of solid axle rail vehicles is known to be a strong function of primary suspension stiffness, wheel/rail profile geometry (conicity and gravitational stiffness), wheel/rail friction forces (creep coefficients), bogie/carbody inertia properties, and secondary suspension design. This paper deals with the problem of maximizing the critical speed through design of the primary and secondary suspension but with control only over the range of wheel/rail geometry and friction characteristics.

SHIPS

86-788
Probabilistic Analysis of the Combined Slamming and Wave-Induced Responses
G. Ferro, A.E. Mansour
Registro Italiano Navale, Genoa, Italy
J. Ship Res., 29 (3), pp 170-188 (Sept 1985) 12 figs, 3 tables, 31 refs

KEY WORDS: Cargo ships, Slamming, Wave forces

The success of implementing reliability analysis in structural design depends to a large extent on the ability to combine the loads acting on the structure, and on extrapolating their magnitudes to obtain the extreme value of the total combined load. A new theory is proposed to combine the slamming and wave-induced responses of a ship moving in irregular seas. An example of application to a cargo ship is given and a sensitivity analysis is conducted to determine how sensitive the results are to some of the important input parameters.

86-789
Torsional Response of Containerships
P. Terndrup Pedersen
The Technical Univ. of Denmark, Lyngby, Denmark
J. Ship Res., 29 (3), pp 194-205 (Sept 1985) 14 figs, 13 refs

KEY WORDS: Cargo ships, Torsional response

A consistent beam model for calculation of static and dynamic horizontal torsional response of containerships with large hatch openings is presented. Based on a beam theory which describes the response of smooth hull segments and on discontinuity conditions which provide some compatibility between closed and open cross sections, a mathematical model is developed that takes into account the restraining effect of short beam-like deck strips as well as wider deck areas. A numerical solution procedure is presented which requires only very limited computer core and time.

AIRCRAFT

86-790
Aerodynamic Characteristics of the Standard Dynamics Model in Coning Motion at Mach 0.6
C. Jermey, L.B. Schiff
NASA Ames Res. Ctr., Moffett Field, CA
Rept. No. REPT-85215, NASA-TM-86717, 75 pp (July 1985) N85-32094/3/GAR

KEY WORDS: Aircraft, Aerodynamic characteristics

A wind tunnel test was conducted on the standard dynamics model undergoing coning motion at Mach 0.6. Six component force and moment data are presented for a range of angle of attack, sideslip, and coning rates. At the relatively low non-dimensional coning rate employed, the lateral aerodynamic characteristics generally show a linear variation with coning rate.

86-791
Calculation of Transonic Steady and Oscillatory Pressures on a Low Aspect Ratio Model and Comparison with Experiment
R.M. Bennett, E.C. Wynne, D.G. Mabey
NASA Langley Res. Ctr., Hampton, VA
Rept. No. NASA-TM-86449, 18 pp (June 1985) N85-32092/7/GAR

KEY WORDS: Aircraft, Aerodynamic characteristics

Pressure data measured by the British Royal Aircraft Establishment for the AGARD SMP tailplane are compared with results calculated using the transonic small perturbation code XTRAN3S. A brief description of the analysis is given and a recently developed finite difference grid is described. Results are presented for five steady and nine harmonically oscillating cases, near zero angle of attack and for a range of subsonic and transonic Mach numbers.

86-792
Recent Developments in Rotary-Balance Testing of Fighter Aircraft Configurations at NASA Ames Research Center
G.N. Malcolm, L.B. Schiff
NASA Ames Res. Ctr., Moffett Field, CA
Rept. No. REPT-85211, NASA-TM-86714, 28 pp (July 1985) N85-32090/1/GAR

KEY WORDS: Aircraft, Aerodynamic characteristics, Test facilities, Wind tunnel testing

Two rotary balance apparatuses were developed for testing airplane models in a coning motion. Effects of spin rate parameter and description of the two rigs and a discussion of some of the results obtained in the respective tests are presented.

86-793
Estimation of Unsteady Aerodynamic Loads in Turbulence (Abschätzung von stochastischen Böenlasten unter Berücksichtigung instationärer Luftkrafte)
G. Schanzer
Institut für Flugführung der Technischen Universitat, Fed. Rep. Germany
Z. Flugwiss. Weltraumforsch., 9 (3), pp 167-178 (May/June 1985) 21 figs, 2 tables, 27 refs (in German)

KEY WORDS: Aircraft, Aerodynamic loads, Turbulence

A procedure to estimate the unsteady aerodynamic loads when flying in turbulence is discussed. The degree of gust alleviation as a function of altitude, Richardson number and mean wing chord can be calculated using simple formulas.

86-794
The Theory of Oscillating Thick Wings in Subsonic Flow. Lifting Line Theory
L. Dragos
Univ. of Bucharest, Bucharest, Romania
Acta Mech., 54 (3/4), pp 221-238 (Mar 1985) 15 refs

KEY WORDS: Aircraft wings, Fluid-induced excitation

On the basis of the fundamental solutions method developed in previous papers, a theory of oscillating thick wings in subsonic flow is presented. The representation of the general solution for arbitrary wings and the integral equation of the problem are obtained. General solutions and integral equations for the incompressible fluid and for two and three dimensional motion at Mach number one are also presented. IN the last part of the paper the theory of oscillating lifting line is given.

86-795
Effects of Viscosity and Modes on Transonic Aerodynamic and Aeroelastic Characteristics of Wings
G.P. Guruswamy, J.W. Marstiller, H.T.Y. Yang, P.M. Goorjian
NASA Ames Research Center, Moffett Field, CA
J. Aircraft, 22 (9), pp 756-762 (Sept 1985) 11 figs, 2 tables, 13 refs

KEY WORDS: Aircraft wings, Aerodynamic loads, Viscocity effects, Mode shapes

The research reported in this paper is concerned with aerodynamic and aeroelastic computations in the transonic regime. The aerodynamic computations were made using small-disturbance, unsteady, transonic theory with viscous corrections. Areas of investigation included higher structural modes in addition to the fundamental bending and torsion modes in transonic aeroelastic analyses. Two wings were studied, a rectangular wing with a NACA 64A010 airfoil section, and a swept wing, with a MBB-A3 supercritical airfoil section.

86-796
Further Investigations to Improve the Fatigue Life of the Mirage IIID Wing Span Spar
J.Y. Mann, A.S. Machin, W.F. Lupson
Aeronautical Res. Labs., Melbourne, Australia
Rept. No. ARL/STRUC-TM-397, 36 pp (Jan 1985) AD-A157 896/2/GAR

KEY WORDS: Aircraft wings, Fatigue life

Wing main spars of Mirage IIID aircraft have undergone a refurbishment program to extend their fatigue lives by the installation of interference fit steel bushes. A supplementary investigation has been carried out to assess two potential techniques for reducing the influence of empty rivet holes (namely the installation of interference-fit steel pins and adhesively-bonded aluminum rivets), and to assess the improvements in fatigue life which might be introduced by a redesign of the spar at the previously critical location.

86-797
Noise Radiation Patterns of Counter-Rotation and Unsteadily Loaded Single-Rotation Propellers
P.J.W. Block

NASA Langley Research Center, Hampton, Virginia
J. Aircraft, 22 (9), pp 776-783 (Sept 1985) 14 figs, 1 table, 10 refs

KEY WORDS: Aircraft propellers, Sound, Wave propagation

In order to understand the effects of installation on propeller noise, numerous measurements are required to define the directivity of the noise as well as the level. An experimental study was designed to map the noise radiation pattern for various single-rotation propeller (SRP) installations and one counter-rotation propeller (CRP).

BIOLOGICAL SYSTEMS

HUMAN

86-798
Meter Measures Ride Comfort
J.J. Wood, J.D. Leatherwood
Wyle Labs.
SAE Paper No 85098 (P-161)

KEY WORDS: Noise measurement, Automobiles, Interior noise, Human response

An extensive research program has been conducted to develop a comprehensive model for estimating passenger comfort response to combined interior noise and vibration environments typical of transportation vehicles. This model is intended for use in designing vehicles and for comparative assessment/diagnosis of ride quality for current vehicles.

MECHANICAL COMPONENTS

ASORBERS AND ISOLATORS

86-799
Periodically Layered Composites for Attenuation of Dynamic Loads
A.K. Ghosh
Bhabha Atomic Research Centre, Bombay, India
Nucl. Engrg. Des., 84 (1), pp 53-58 (Jan 1985) 7 figs, 1 table, 5 refs

KEY WORDS: Mountings, Shock absorbers, Layered materials, Bars

The dynamic response of periodically layered media shows attenuation of stresses and suggests their use as shock mountings. The basic attenuation characteristics of a composite subjected to harmonic excitation is presented and applicability by the response of an elastic bar with such a mounting so as to input stress and base motion is illustrated.

86-800
New Proposed Dynamic Vibration Absorbers for Excited Structures
H.F. Bauer
Hochschule der Bundeswehr Muenchen, Neubiberg, Fed. Rep. Germany
(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1986, AD-A152 547, pp DD-1 - DD-27) AD-P004 712/6/GAR

KEY WORDS: Dynamic vibration absorption (equipment), Fluid-filled containers, Spacecraft

Structural systems are very susceptible to oscillators. There exist not too many effective systems to dampen the dangerous motion of the structure. The more effective vibration absorbers have some disadvantages such as the adjustment, blockage and servicing. They can therefore not be employed in space structures. A new damping device consisting of a completely filled liquid container filled with two immiscible liquids, in which the motion of the interface is able to effectively dampen the structure is suggested.

86-801
A New Procedure for Optimum Design of Vibration Absorbers for Automobile Engines
Zhengchang Xu
Ph.D. Thesis, Queen's Univ. at Kingston (Canada), (1985)

KEY WORDS: Vibration absorption (equipment), Crankshafts, Automobile engines, Optimum design

A new method for determining the forced torsional vibration amplitudes and a new procedure for optimum design of a rubber crankshaft vibra-

tion absorber for automobile engines are presented. A complex idealized mathematical model is established. It is a multi-mass formulation, containing all gas torques of the individual cylinders and all types of damping of the individual engine parts. In particular, the dry friction damping, a nonlinear damping, caused by auxiliaries is brought into the model. Finally, a computer program package "DAMPACK" and its user's manual are presented.

86-802
Advances in Suspension and Steering
A. Baker
Auto. Engr. (UK), 10 (3), pp 26-29 (June/July 1985) 5 figs

KEY WORDS: Suspension systems (vehicles)

A survey of how the automobile industry is developing is presented. The six main areas that warrant attention are: active and semi-active suspension systems; air/fluid-displacement and rubber systems; sophisticated struts no covered above, springs, including the composite variety; power-assisted steering systems and other components.

86-803
Seismic Isolation for Nuclear Power Plants: Technical and Non-Technical Aspects in Decision Making
J.M. Eidinger, J.M. Kelly
Impell Corporation, Walnut Creek, CA
Nucl. Engrg. Des., 84 (3), pp 383-409 (Feb 1985) 21 figs, 6 tables, 17 refs

KEY WORDS: Seismic isolation, Nuclear power plants

Technical aspects of seismic isolation systems show merit for their use in nuclear power plants. Less quantifiable non-technical aspects must be evaluated in the decision to employ a seismic isolation system Both aspects are discussed.

86-804
Issues in Seismic Isolation of Nuclear Power Plants
A.H. Hadjian, W.S. Tseng
Bechtel Power Corp., Los Angeles and San Francisco, CA
Nucl. Engrg. Des., 84 (3), pp 433-438 (Feb 1985) 4 figs, 3 refs

KEY WORDS: Nuclear power plants, Seismic isolation

The issues involved in considering seismic isolation for nuclear plants are covered. The application of isolation techniques to non-nuclear installations is discussed. Its potential application to nuclear components and plants is considered and the lack of actual, experimental verification of novel techniques is portrayed. A cost comparison, based on certain preliminary assumptions of isolated and non-isolated nuclear plants is made.

86-805
Damping Characteristic Identification for a Nonlinear Seismic Isolation System
V.F. Poterasu
Polytechnic Institute of Jassy, Romania
Nucl. Engrg. Des., 84 (1), pp 59-65 (Jan 1985) 5 figs, 2 tables, 11 refs

KEY WORDS: Seismic isolation, Periodic response, Damping coefficients, Phase resonance method

The steady-state response of structures to harmonic excitation is of both direct and indirect importance. Such a response is of obvious direct importance in problems which involve excitation from rotating machinery or other sources of steady harmonic excitation. It is also of indirect importance in problems involving transient excitation where knowledge of the harmonic response may be used in estimating and interpreting the transient structural response. A phase resonance method is given for damping characteristic identification of the nonlinear device seismic isolation in the harmonic excitation case.

86-806
Seismic Isolation Using Sliding-Elastomer Bearing Pads
R. Guéraud, J.-P. Noël-Leroux, M. Livolant, A.P. Michalopoulos
Electricité de France - SEPTEN, Paris, France
Nucl. Engrg. Des., 84 (3), pp 363-377 (Feb 1985) 13 figs, 1 table, 13 refs

KEY WORDS: Seismic isolation, Nuclear power plants, Elastomers

Seismic isolation of nuclear power plants using sliding-elastomer bearing pads is reviewed. The foundation system involves a double raft interposed with reinforced neoprene pads and friction plates. All safety related structures are founded on the common (or connected) upper raft(s) which is in turn supported by a common lower raft founded on the subsurface soils. The characteristic features of the aseismic foundation system is shown to offer a number of advantages over conventionally designed structures in terms of performance, cost and safety.

86-807

Optimum Characteristics of Isolated Structures

M.C. Constantinou, I.G. Tadjbakhsh
Drexel Univ., Philadelphia, PA
ASCE J. Struc. Engrg., 111 (12), pp 2733-2750 (Dec 1985) 7 figs, 5 tables, 29 refs

KEY WORDS: Base isolation, Optimum design, Seismic design, Buildings

The effect of frequency content of the ground excitation on the optimum design of a base isolation system and a first-story damping system is investigated. The ground excitation is modeled as a filtered white noise with Kanai-Tajimi power spectral density. The stationary response, including peak response, is derived in closed form. Examples show the manner of applying the results of an ordinary two-story structure.

86-808

Alexisismon Isolation Engineering for Nuclear Power Plants

A.S. Ikonomou
University of Patras, Patras, Greece
Nucl. Engrg. Des., 85 (2), pp 201-216 (Mar 1985) 14 figs, 3 tables, 9 refs

KEY WORDS: Base isolation, Nuclear power plants, Seismic design

This paper reviews the special requirements regarding efficiency, licensibility (reliability) and cost which should be met to achieve an optimum base isolated nuclear power plant design. It then describes the Alexissimon-2, patented isolation system developed by the author, underlines its original properties (linearity and separation of functions) and presents a conceptual design of its application to a nuclear power plant. The reliability of the system components is demonstrated.

86-809

Nonlinear Natural Rubber Bearings for Seismic Isolation

C.J. Derham, J.M. Kelly, A.G. Thomas
The Malaysian Rubber Producers' Research Association, Hertford, England
Nucl. Engrg. Des., 84 (3), pp 417-428 (Feb 1985) 5 figs, 24 refs

KEY WORDS: Base isolation, Seismic isolation, Elastomers, Buildings

The results of a ten-year joint research program on the base isolation is summarized. Special rubber bearings have been developed which protect buildings and their contents from earthquake damage without requiring additional mechanical devices to enhance damping or to avoid problems of wind movement. The lack of complexity in the system makes prediction of response more certain and reduces cost. The principles of design are explained and results given for the many experimental investigations of the system.

86-810

Protection for Structures in Extreme Earthquakes: Full Base Isolation (3-D) by the Swiss Seismafloat System

K. Staudacher
Swiss Federal Institute of Technology, Zürich, Switzerland
Nucl. Engrg. Des., 84, pp 343-357 (1985) 11 figs, 1 table, 6 refs

KEY WORDS: Base isolation, Seismic isolation

Full base isolation (FBI. 3-d), an antiseismic concept for structures, adds vertical flexibility to horizontal base isolation. Extensive experimental testing has shown FBI to be a practicable way to reach the final goal of earthquake protection; i.e., elastic behavior of the structural frame in extreme earthquakes.

86-811

New Zealand Seismic Base Isolation Concepts and Their Application to Nuclear Engineering

I.G. Buckle

Computech Engineering Services, Inc., Berkeley, CA
Nucl. Engrg. Des., 84 (1), pp 313-326 (Feb 1985) 11 figs, 25 refs

KEY WORDS: Base isolation, Seismic isolation, Nuclear power plants

Recent New Zealand experience with seismic base isolation and, in particular, that of using mechanical energy dissipators to control response, is described. The experimental and analytical studies undertaken to validate the technique are reviewed and the issues of reliability and cost are addressed.

86-812
Full Base Isolation for Earthquake Protection by Helical Springs and Viscodampers
G.K. Hüffmann
GERB, Gesellschaft für Isolierung mbH&Co., Essen, Fed. Rep. Germany
Nucl. Engrg. Des., 84, pp 331-338 (1985) 8 figs, 8 refs

KEY WORDS: Base isolation, Seismic isolation, Springs, Viscous damping

A new system for three dimensional earthquake protection of whole structures, based on helical springs with definite linear flexibility of similar order in all three dimensions and velocity proportional viscodampers is described. This system has been successfully used for the installation of large diesel- and turbo-generators in seismic zones where earthquake protection has been combined with conventional vibration control concepts

TIRES AND WHEELS

86-813
The Equations of Motion of a Dicone Moving on a Pair of Circular Cylinders
A.D. de Pater
Delft Univ. of Technology, Delft, The Netherlands
Ind. J. Nonlin. Mech., 20 (5/6), pp 439-449 (1985) 6 figs, 5 refs

KEY WORDS: Railway wheels, Wheelsets, Circular cylinders

Many aspects of the motion of a railway wheelset are investigated from a model consisting of a dicone moving on a pair of circular cylinders. It is shown how the exact equations of motion can be established for this model.

BLADES

86-814
Experimental Study of Aerodynamic Damping Characteristics of a Compressor Annular Cascade in High Speed Flow and the Visualization of Annular Cascade Flow
H. Kobayashi
National Aerospace Lab., Tokyo, Japan
Rept. No. NAL/TR-838, 23 pp (1984) PB85-230308/GAR (in Japanese)

KEY WORDS: Compressor blades, Aerodynamic damping, Fluid-induced excitation

To clarify experimentally the characteristics of aerodynamic damping of a compressor cascade in high speed flow, which is an important factor of blade oscillatory fatigue, the time-variant aerodynamic pressure acting on the blade surface of harmonically oscillated annular cascade in torsional mode was measured with a Freon gas annular cascade test facility over a range from high subsonic to supersonic and over a wide range of reduced frequencies. Through these data, the variance of cascade aerodynamic stability for inlet flow Mach number and reduced frequency, and the effects of shock wave movement due to blade oscillation on an unsteady aerodynamic force and on an aerodynamic stability of the cascade were made clear.

86-815
Impulsive Noise Due to Transonic Blade-Vortex Interactions
Shyue-Bin Chang
Ph.D. Thesis, Cornell Univ., 173 pp (1985) DA8504496

KEY WORDS: Blade-vortex interaction, Helicopter noise, Computer programs

Two mechanisms cause helicopter impulsive noise. High-speed compressibility noise is almost fully understood, but blade-vortex interaction noise is not yet well understood. The

phenomenon of blade-vortex interactions on full scale helicopters is shown to be fundamentally associated with transonic flow phenomenon which can be modeled as two-dimensional. A numerical approach was followed to simulate the two-dimensional blade-vortex interactions. Based on the LTRAN2 code which computes the low-frequency, unsteady, small disturbance velocity potential for transonic flow, a modified version -- VTRAN2 -- was developed to calculate the near-field potential of the blade-vortex interaction.

86-816

Pressure Fluctuations on Rotor Blades Generated by Blade-Vortex Interaction

G. Neuwerth, R. Müller

Technical University of Aachen, Aachen, Fed. Rep. Germany

Vertica, 9 (3), pp 227-239 (1985) 21 figs, 13 refs

KEY WORDS: Helicopters, Propeller blades, Fluid-induced excitation, Vortex-induced vibration

During some flight operations of helicopters the main rotor blades pass close to or intersect the trailing tip vortices of the main rotor. These blade-vortex interactions (BVI) generate strong fluctuating blade pressures leading to dynamic structural loads and impulsive noise radiation. Currently accurate load predictions are limited by the lack of knowledge of the tip vortex structure. A special test facility, built to investigate the basic mechanism of BVI, is described.

86-817

Aircraft Rotor Blade with Passive Tuned Tab

T.G. Campbell

NASA Ames Res. Ctr., Moffett Field, CA

U.S. PATENT 4 514 143, 10 pp (Apr 30, 1985)

KEY WORDS: Aircraft, Rotor blades, Vibration control, Aerodynamic loads, Structural modification techniques

A structure for reducing vibratory airloading in a rotor blade with a leading edge and a trailing edge, including a cut out portion at the trailing edge, is described.

BEARINGS

86-818

Lateral Dampers for Thrust Bearings

D.H. Hibner, D.R. Szafir

NASA Lewis Res. Ctr., Cleveland, OH

Rept. No. PWA-5966-17, 63 pp (Aug 1985) 35 figs, 16 refs

KEY WORDS: Thrust bearings, Damping characteristics

A program focusing on the development of lateral damping schemes for thrust bearings is presented. It rans their applicability to various engine classes, selects the best concept for each engine class and performs an in-depth evaluation. Five major engine classes were considered: large transport, military, small general aviation, turboshaft, and non-manrated.

86-819

A Theoretical Model for the Study of Nonlinear Dynamics of Magnetic Bearings

K.V. Hebbale

Ph.D. Thesis, Cornell Univ., 197 pp (1985) DA 8504533

KEY WORDS: Magnetic bearings

A theoretical model for the study of nonlinear dynamics of magnetic bearings is developed. The systems modeled and studies consist of ferromagnetic mass and rotors suspended by the forces of attraction of one, two and four independent electromagnets. In each case, the model is described by a set of first order nonlinear differential equations. The well known open loop instability is shown in each case.

FASTENERS

86-820

Passively Damped Joints for Advanced Space Structures

R.W. Trudell, L. Rehfield, A. Reddy, J. Prucz

McDonnell Douglas Astronautics Co.-West, Huntington Beach, CA

(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, AD-A152 547, pp DDD-1 - DDD-29) AD-P004 734/0/GAR AD-P004 734/0/GAR

KEY WORDS: Joints, Spacecraft, Vibration damping, Design techniques

In the past, damping treatments have been added to structure rather than designed in. This work-progress paper describes the benefits to be gained by designing damping into the joints of large space structures. Also, an analysis of a typical joint is developed and two new non-resonant test techniques are outlined.

LINKAGES

86-821
Stability of a Manipulator with Resilient Joints
G.L. Anderson
Institut CERAC S.A., Ecublens, Switzerland
J. Sound Vib., 101 (4), pp 463-480 (Aug 22, 1985) 10 figs, 15 refs

KEY WORDS: Robots, Linkages, Flutter

The stability of a manipulator subject to a non-conservative force applied at its free extremity is investigated. The manipulator consists of three rigid links that are connected end-to-end in an open chain. The stability conditions are derived, and numerical values of the critical divergence and flutter loads are computed for various configurations of the manipulator. Stability maps and various plots of the critical loads as functions of the angular orientation of the distal link are included.

86-822
Dynamic Analysis of Robotic Manipulators with Flexible Links
Liang-Wey Chang
Ph.D. Thesis, Purdue Univ., 189 pp (1984) DA8507666

KEY WORDS: Linkages, Robots, Mathematical models

A dynamic model for flexible manipulator systems and a solution method to solve the equations of motion efficiently are developed. The model describes the global motion of the flexible manipulators as a large motion and a small motion. The large motion is represented by the equivalent rigid link system (ERLS) which is kinematically equivalent to the real rigid link system. The small motion represents deformations of the system, relative to the ERLS.

86-823
Dynamic Instability of the Flexible Coupler of a Four-Bar Mechanism
I.G. Tadjbakhsh
Rensselaer Polytechnic Inst., Troy, NY
(Trans. Army Conf. Applied Mathematics and Computing (2nd), Washington, DC, May 22-25, 1984, AD-A154 047, pp 105-116) AD-P004 909/8/GAR

KEY WORDS: Linkages, Four bar mechanisms

Dynamic behavior of the flexible components of mechanisms is prone to instabilities which create resonant speed barriers. By considering small deformations superimposed on the steady dynamic state equations governing evolution of disturbances can be obtained. For the case of mechanisms driven by periodic inputs these equations reduce to a system of coupled Mathieu-Hill equations for the amplitudes of modes of vibration. Application of the Floquet theory determines the critical conditions of speed, geometry and material properties causing dynamic instability.

STRUCTURAL COMPONENTS

CABLES

86-824
Vibration Analysis of Orthogonal Cable Networks by Transfer Matrix Method
B.L. Dhoopar, P.C. Gupta, B.P. Singh
Indian Institute of Technology, Kanpur, India
J. Sound Vib., 101 (4), pp 575-584 (Aug 22, 1985) 7 figs, 1 table, 6 refs

KEY WORDS: Cables, Chains, Natural frequencies, Transfer matrix method

An orthogonal cable network is considered as a chain of interconnected elements. One such chain consists of a number of x-directed pretensioned straight cables meeting orthogonally a y-directed pretensioned cable. For the analysis of free vibration of the network, the transfer matrix method has been used. The formulation consists of obtaining transfer matrices successively for a single cable, a joint, a chain and finally the whole network.

BARS AND RODS

86-825
Influence of Initial Imperfections on Nonlinear Free Vibration of Elastic Bars
I. Elishakoff, V. Birman, J. Singer
Technion Israel Inst. of Tech., Haifa, Israel
Acta Mech., 55, pp 191-202 (July 1985) 15 refs

KEY WORDS: Bars, Elastic properties, Geometric imperfection effects

Nonlinear free vibration of elastic bars possessing initial imperfections is studied. For the vibration frequency the differential equation is solved exactly in terms of complete elliptic integrals. Numerical results demonstrate that the initial imperfections usually reduce the frequency of nonlinear free vibration of elastic bars subjected to moderate compression, but there are exceptions with the opposite effect.

86-826
A General Normal Mode Solution for the Free Vibration of the Rectangular Parallelepiped
E.v.K. Hill
Morton Thiokol, Brigham City, UT
J. Acoust. Soc. Amer., 78 (4), pp 1344-1347 (Oct 1985) 1 fig, 19 refs

KEY WORDS: Rectangular bars, Normal modes

A general normal mode solution is presented for the free vibration of the rectangular parallelepiped with arbitrary, static boundary conditions and body forces. This is followed by three examples of the solution procedure. Dynamic body forces and boundary conditions are also considered.

BEAMS

86-827
Response of an Axially Loaded Timoshenko Beam to Random Loads
J.R. Banerjee, D. Kennedy
University of Wales Institute of Science and Technology, Cardiff, Wales
J. Sound Vib., 101 (4), pp 481-487 (Aug 22, 1985) 3 figs, 8 refs

KEY WORDS: Beams, Timoshenko theory, Random response

Theoretical expressions for the displacement response of an axially loaded Timoshenko beam subjected to concentrated or distributed random loads having stationary and ergodic properties is presented. The method is illustrated by its application to investigate the effects of axial force on the random response of a simply supported beam acted upon by an ideal white noise.

86-828
Beam Element Matrices Derived from Vlasov's Theory of Open Thin-Walled Elastic Beams
P.O. Friberg
Chalmers Univ. of Technology, Gothenburg, Sweden
Intl. J. Numer. Methods Engrg., 21 (7), pp 1205-1228 (July 1985) 4 figs, 20 refs

KEY WORDS: Beams, Dynamic stiffness, Matrix methods

A uniform beam element of open thin-walled cross-section is studied under stationary harmonic end excitation. An exact dynamic (transcendentally frequency-dependent) 14 x 14 element stiffness matrix is derived from Vlasov's coupled differential equations. Special attention is paid to the computational problems arising when coefficients vanish in these equations because of symmetric cross-section, zero warping stiffness, etc.

86-829
Stability of Continuously Restrained Cantilevers
M. Assadi, C.W. Roeder
Univ. of Washington, Seattle, WA
ASCE J. Engrg. Mech., 111 (12), pp 1440-1456 (Dec 1985) 14 figs, 1 table, 26 refs

KEY WORDS: Cantilever beams, Torsional response

The problem of lateral torsional stability of cantilevers with continuous elastic or rigid lateral restraint is examined via a direct variational approach and in view of three major influence parameters. The derived free-end force boundary conditions are examined and a quandry regarding their validity is addressed. The results of an experimental study are reported, providing some guidance in assessing the buckling of continuously restrained cantilevers.

86-830

Parameter Identification in Continuum Models

H.T. Banks, J.M. Crowley
Brown Univ., Providence, RI
J. of the Astronautical Sci., 33 (1), pp 85-94 (Jan-Mar 1985)

KEY WORDS: Continuous beams, Parameter identification techniques, Bernoulli-Euler method

Approximation techniques for use in numerical schemes for estimating spatially varying coefficients in continuum models such as those for Euler-Bernouli beams are discussed. The techniques are based on quintic spline state approximations and cubic or linear spline parameter approximations. Both theoretical and numerical results are presented.

86-831

An Investigation of the Dispersion Law for I-Section Beams

J.R. Chapman, D. Butler, P.R. Brazier-Smith
The Plessey Company Limited, Somerset, England
J. Sound Vib., 102 (4), pp 563-577 (Oct 22, 1985) 13 figs, 5 refs

KEY WORDS: Beams, Timoshenko theory, Flexural vibrations, Wave dispersion, Viscoelastic damping

A method for deriving the dispersion law for I-section beams is presented, which explains discrepancies between experiment and the Timoshenko beam equation. The discrepancies are accounted for by allowing the flanges of the model beam to vibrate. The method is confirmed experimentally for different I-section shapes. Application of viscoelastic damping material to the flanges is found to have only small effects on the dispersion law, but flange vibration results in increased loss factors at higher frequencies.

86-832

Effect of a Viscoelastic Boundary Inset on Vibrational Characteristics of a Beam

M. Ilkhani-Pour
Ph.D. Thesis, Purdue Univ., 144 pp (1984) DA8507695

KEY WORDS: Beams, Flexural vibrations, Viscoelastic damping

The effect of a viscoelastic (elastomeric) inset on the vibrational characteristics of a cantilevered beam in flexural motion is examined. The inset is placed at the support fixture of the beam. A closed form solution is obtained for the cyclic energy dissipation due to the inset. The validity of analytical results are confirmed by a good comparison with available test data in the literature. Expressions are then developed for the effect of the inset on fundamental natural frequency and damping ratio of the beam.

86-833

Vibrations of Beams Fully or Partially Supported on Elastic Foundations

M. Eisenberger, D.Z. Yankelevsky, M.A. Adin
Technion-Israel Institute of Technology, Haifa, Israel
Earthquake Engrg. Struc. Dynam., 13 (5), pp 651-600 (Sept/Oct 1985) 12 figs, 14 refs

KEY WORDS: Beams, Elastic foundations, Natural frequencies, Mode shapes, Matrix methods

Exact stiffness and consistent mass matrices for beams on elastic foundations are derived. Using these matrices it is possible to find the natural frequencies and mode shapes of vibrations, for beams fully or partially supported on elastic foundations. Several examples are given.

CYLINDERS

86-834

Flow Induced Oscillations of Two Interfering Circular Cylinders

M.M. Zdravkovich
Univ. of Salford, Salford, England
J. Sound Vib., 101 (4), pp 511-521 (Aug 22, 1985) 6 figs, 10 refs

KEY WORDS: Circular cylinders, Fluid-induced excitation, Vortex-induced vibration

Flow interference between two circular cylinders in various arrangements, which imposes continuous and discontinuous changes in vortex shedding, is studied. The resulting oscillations induced by the vortex shedding are considerably modified by and strongly depend on the arrangement of the two cylinders. A systematic classification of flow interference regimes is linked to

the observed vortex shedding responses for a wide range of arrangements. The discontinuous change of flow regimes in some arrangements can excite and maintain large amplitude oscillations beyond a certain critical velocity.

86-835
A Boundary Integral Equation Approach to the Transient Oscillations of Freely Floating Long Cylinders
U. Kanik
Ph.D. Thesis, Polytechnic Inst. of New York, 76 pp (1985) DA8506853

KEY WORDS: Floating structures, Circular cylinders, Impact excitations, Transient response, Computer programs

The boundary integral method which has been applied to the solution of initial value problems associated with the motion of floating bodies is described. An unknown distribution function of wave sources over the wetted surface is assumed, in terms of which the fluid velocities and pressures are expressed. The differential equation of motion of the body is coupled to the fluid through the pressure, and the fluid field is coupled to the motion of the body through the velocity continuity condition. The problem is reduced to the solution of a set of integral equations with the unknowns being the body displacements and the source density function.

86-836
Dynamic Response in an Elastic-Plastic Projectile Due to Normal Impact
P.C.T. Chen, J.E. Flaherty, J.D. Vasilakis
Army Armament Res. and Dev. Ctr., Watervliet, NY
(Trans. Army Conf. Applied Mathematics and Computing (2nd) Washington, DC, May 22-25, 1984, AD-A154 047, pp 839-858) AD-P004 952/8/GAR

KEY WORDS: Circular cylinders, Impact response, Finite element technique, Computer programs

A numerical study of the dynamic response of an elastic-plastic projectile due to normal impact has been made using the finite element structural response code ADINA. The projectile is a finite length circular cylindrical bar striking a rigid target. Three direct integration schemes were used for unaxial stress wave problems in a linear-hardening material and the results were compared with an exact analytical solution in order to evaluate accuracy and stability.

86-837
Limit-Cycle Vibrations of a Rolling Cylinder
S.H. Crandall, G. Pariseanu
Massachusetts Institute of Technology, Cambridge, MA
Intl. J. Nonlin. Mech., 20 (5/6), pp 385-393 (1985) 7 figs, 8 refs

KEY WORDS: Textile spindles, Cylinders, Limit cycle analysis

An explanation for a violent vibration of a high-speed textile yarn winder is proposed based on the hypothesis that variations in radial compliance around the circumference of the yarn cylinder make the smooth winding process unstable due to parametric excitation. The amplitude of the resulting limit cycle depends on the nonlinearity in the radial compliance. An analytical procedure for predicting the limit-cycle amplitude is developed and applied to a specially constructed mechanical model of a yarn winder.

86-838
Forced Vibrations of an Isotropic, Perfectly Plastic Circular Cylinder Having a Rigid Cylindrical Inclusion
V.P. Muthuswamy, T. Raghavan
Rev. Roumaine Sci. Tech., Mecanique Appl., 29 (6), pp 651-655 (Nov/Dec 1984) 4 refs

KEY WORDS: Circular cylinders, Forced vibrations, Discontinuity-containing media

The forced vibrations of an isotropic, circular cylinder, having a cylindrical rigid inclusion, are considered. Laplace transforms and complex inversion functions are used to arrive at the solution.

FRAMES AND ARCHES

86-839
Seismic Response of RC Frames with Steel Braces
A.K. Jain

Univ. of Roorkee, Roorkee, India
ASCE J. Struc. Engrg., 111 (10) pp 2138-2148 (Oct 1985) 7 figs, 3 tables, 22 refs

KEY WORDS: Frames, Reinforced concrete, Seismic response

Steel bracing members are widely used in steel structures to reduce lateral displacements and dissipate energy during strong ground motions. This concept is extended to concrete frames. Inelastic seismic response of reinforced concrete frames with K and X steel bracing patterns is presented.

86-840
Lateral Load Response of Flat-Plate Frame
J.P. Moehle, J.W. Diebold
Univ. of California, Berkeley, CA
ASCE J. Struc. Engrg., 111 (10), pp 2149-2164 (Oct 1985) 9 figs, 1 table, 19 refs

KEY WORDS: Frames, Seismic response, Base excitation, Experimental data, Lateral response

Lateral-load response of a flat-plate frame under simulated earthquake base motions is examined. The test structure is a three-tenths scale model of a two-story, three-bay flat plate frame, which was designed and detailed according to current procedures for beamless slabs in regions of moderate seismic risk. Overall resistance to low, moderate, and high intensity base motions is examines, and design-oriented methods to evaluate lateral-load stiffness and strength are examined.

86-841
Dynamics of Trusses by Component-Mode Method
W. Weaver, Jr., C.L. Loh
Stanford Univ., Stanford, CA
ASCE J. Struc. Engrg., 111 (12), pp 2565-2575 (Dec 1985) 7 figs, 1 table, 7 refs

KEY WORDS: Frames, Trusses, Component mode analysis, Beams

For dynamic analysis of trusses usually only axial deformations in the members are considered. However, it is known that inertial and body forces occur along the members in their transverse directions, which cause flexure. Therefore, a component-mode analytical model has been devised in which a member in bending constitutes a substructure.

86-842
Design of Seismic-Resistant Friction-Braced Frames
M.A. Austin, K.S. Pister
Univ. of California, Berkeley, CA
ASCE J. Struc. Engrg., 111 (12), pp 2751-2769 (Dec 1985) 10 figs, 15 refs

KEY WORDS: Frames, Seismic design, Computer aided techniques

This paper illustrates the design of a ten-story, single bay, earthquake-resistant friction-braced steel frame using a computer-aided design system called DELIGHT.STRUCT. Linear and nonlinear time history analyses are built into the design procedure itself rather than serving as a check at the end of the design process. The frame's performance is assessed on the basis of its response to gravity loads alone, gravity loads plus a moderate earthquake, and finally gravity loads combines with a rare severe earthquake ground motion.

MEMBRANES, FILMS AND WEBS

86-843
Dynamic Behavior of a Very Flexible Membrane Rotating on a Gas Film Next to a Wall
Y. Sato
Saitama Univ., Urawa, Japan
Acta Mech., 55 (1/2), pp 95-104 (Apr 1985) 5 figs

KEY WORDS: Membranes, Cylindrical bodies

The dynamic behavior of a cylindrical membrane and a circular membrane rotating on a thin gas film is studies theoretically. It is demonstrated that in some cases a wavy deflection shape of a membrane moves forward at about half of the rotating speed and that the motion is very slowly damped out.

PLATES

86-844
Dynamic Analysis of Orthotropic Plate Structures
N.F. Grace, J.B. Kennedy

Giffels Assoc., Southfield, MI
ASCE J. Engrg. Mech., 111 (8), pp 1027-1037 (Aug 1985) 7 figs, 2 tables, 12 refs

KEY WORDS: Plates, Orthotropism, Natural frequencies, Beams

The dynamic response of orthotropic plate structures having fixed-simply supported and free-free boundary conditions is investigated using orthotropic plate theory. The influences of aspect ratio and rigidity ration on the natural frequencies are examined and compared to those obtained from beam-theory. The analytical results, verified by experimental test results, confirm that for this class of structures the natural frequencies beyond the first cannot be reliably estimated by beam theory.

86-845
Membrane-Type Eigenmotions of Mindlin Plates
H. Irschik
Technical Univ. Vienna, Austria
Acta Mech., 55 (1/2), pp 1-20 (Apr 1985) 3 figs

KEY WORDS: Plates, Mindlin theory, Eigenvalue problems

A membrane analogy is presented for eigenvalue problems of simply supported Mindlin plates of arbitrary polygonal planform. Influence of hydrostatic inplane forces and Pasternak-type foundation of the plate domain is taken into account. Analytical results are derived in a non-dimensional form, which, using the analogous membrane eigenvalues as parameters, is independent of the special shape of the plate.

86-846
Natural Frequencies of Rectangular Plates Using Characteristic Orthogonal Polynomials in Rayleigh-Ritz Method
R.B. Bhat
Concordia University, Montreal, Quebec, Canada
J. Sound Vib., 102 (4), pp 493-499 (Oct 22, 1985) 4 tables, 14 refs

KEY WORDS: Rectangular plates, Natural frequencies, Rayleigh-Ritz method

Natural frequencies of rectangular plates are obtained by employing a set of beam characteristic orthogonal polynomials in the Rayleigh-Ritz method. The orthogonal polynomials are generated by using a Gram-Schmidt process, after the first member is constructed so as to satisfy all the boundary conditions of the corresponding beam problems accompanying the plate problems. Natural frequencies obtained by using the orthogonal polynomial functions are compared with those obtained by other methods.

86-847
Vibrating Nonuniform Plates on Elastic Foundation
P.A.A. Laura, R.H. Gutierrez
Inst. of Applied Mechanics, Puerto Belgrano Naval Base, Argentina
ASCE J. Engrg. Mech., 111 (9), pp 1185-1196 (Sept 1985) 4 figs, 10 tables, 9 refs

KEY WORDS: Plates, Elastic foundations, Variable cross section

Circular plates of variable thickness and elastically restrained against rotation along the edge resting on a Winkler-Pasternak medium are addressed. Free and forced vibrations are studied using a very simple polynomial coordinate function and the Ritz method. The entire algorithmic procedures can be efficiently handled using a microcomputer.

86-848
Non-Linear Vibration of Anisotropic Rectangular Plates with Non-Uniform Edge Constraints
C.Y. Chia
University of Calgary, Calgary, Alberta, Canada
J. Sound. Vib., 101 (4), pp 539-550 (Aug 22, 1985) 8 figs, 3 tables, 17 refs

KEY WORDS: Rectangular plates, Flexural vibrations

This paper deals with large-amplitude flexural vibrations of an anisotropic rectangular plate with parallel edges having the varying rotational constraints to the same degree. On the basis of dynamic von Kamaran-type plate equations, a single-mode analysis is carried out. Numerical results for the amplitude-frequency response of generally orthotropic plates are presented for various high-modulus composite materials, orientation angles, aspect ratios, and boundary conditions. Present results for special cases are compared with available data.

86-849

Free Vibration of an Oblique Rectangular Prismatic Shell

T. Irie, G. Yamada, Y. Kobayashi
Hokkaido Univ., Sapporo, Japan
J. Sound. Vib., 102 (4), pp 501-513 (Oct 22, 1985) 6 figs, 3 tables, 7 refs

KEY WORDS: Shells, Prismatic bodies, Natural frequencies, Mode shapes,

An analysis is presented for the free vibration of an oblique rectangular prismatic shell. The dynamical energies of the shell are evaluated, and the frequency equation is derived by the Ritz method. This method is applied to a free-clamped oblique shell truncated by a plane, and the natural frequencies and the mode shapes are calculated numerically up to higher modes.

86-850

Harmonic Response of Rotating Cylindrical Shells

C.H.J. Fox, D.J.W. Hardie
Univ. of Nottingham, Nottingham, England
J. Sound Vib., 101 (4), pp 495-510 (Aug 22, 1985) 5 figs, 4 tables, 15 refs

KEY WORDS: Cylindrical shells, Harmonic response, Axial excitation

Results derived from Flugge thin shell theory are presented which illustrate the effects due to a small, constant axial rotation upon a thin cylindrical shell with various end conditions. It is shown that the rotation produces changes in the modal pattern which cause a build-up of amplitude, proportional to the magnitude of the rotation, where previously a node existed. The dependence upon the rotation of other quantities, such as relative phases of the shell displacements, are examined.

86-851

Orthotropic Annular Shells on Elastic Foundations

Y. Nath, R.K. Jain
Indian Inst. of Technology, New Delhi, India
ASCE J. Engrg. Mech., 111 (10), pp 1242-1256 (Oct 1985) 11 figs, 4 tables, 24 refs

KEY WORDS: Spherical shells, Elastic foundations, Orthotropism

Theoretical nonlinear transient analysis of orthotropic annular shallow spherical shells interacting with Winkler-Pasternak elastic subgrades is performed. The governing of nonlinear equations of motion are derived and solved in space and time domains employing Chebyshev polynomials and implicit Houbolt time-marching technique, respectively.

86-852

Response of Tanks to Vertical Seismic Excitations

M.A. Haroun, M.A. Tayel
Univ. of California, Irvine, CA
Earthquake Engrg. Struc. Dynam., 13 (5), pp 583-595 (Sept/Oct 1985) 7 figs, 6 tables, 12 refs

KEY WORDS: Storage tanks, Seismic response

A method for analyzing the earthquake response of elastic, cylindrical liquid storage tanks under vertical excitations is presented. The method is based on superposition of the free axisymmetrical vibrational modes obtained numerically by the finite element method. The validity of these modes has been checked analytically and the formulation of the load vector has been confirmed by a static analysis.

86-853

Dynamic Analysis of Liquid Storage Tanks Subjected to Seismic Excitation

J.K. Arros
Ph.D. Thesis, Stanford Univ., 147 pp (1985) DA8506156

KEY WORDS: Storage tanks, Seismic excitation

In past earthquakes, cylindrical ground-supported liquid storage tanks have suffered damages of different types. To improve understanding of the phenomena involved, a finite element model with a direct time-stepping transient algorithm is constructed to analyze the response of the liquid-tank system to horizontal and vertical ground excitations. The model has capabilities for the analysis of large amplitude sloshing, convective, impulsive, and static effects of liquid response. The liquid-shell interaction is realized by using sliding interface elements. Either linear or large deformations shell formulations can be incorporated into the model.

86-854
Propagation and Reflection of Waves in Finite Length Liquid-Filled Distensible Shells
T.B. Moodie, D.W. Barclay
Univ. of Alberta, Edmonton, Alberta, Canada
Acta. Mech., 56, pp 151-163 (Sept 1985), 2 figs, 14 refs

KEY WORDS: Tubes, Fluid-filled containers, Wave reflection, Wave propagation

Employing a previously established theory for wave propagation in liquid-filled distensible tubes, the propagation and subsequent reflection of a transient pulse from the distal end of a finite length tube is analyzed. Conditions pertaining to pulse generation at the proximal end of the tube are specified so as to approximate the conditions of experiments carried out on water-filled latex tubes. Laplace transforms are employed and numerical results presented graphically.

86-855
On Global Motions of Articulated Tubes Carrying a Fluid
P.R. Sethna, Xue Min Gu
Univ. of Minnesota, Minneapolis, MN
Intl. J. Nonlin. Mech., 20 (5/6), pp 453-469 (1985) 4 figs, 5 refs

KEY WORDS: Tubes, Fluid-filled containers

Global three-dimensional motions of articulated tubes conveying a fluid are studies by analytical as well as numerical methods. Several different kinds of limiting configurations and bifurcation phenomena are shown to occur in this system.

86-856
Flow-Induced Instability of an Elastic Tube with a Variable Support
W.S. Edelstein, S.S. Chen
Argonne National Laboratory, Argonne, IL
Nucl. Engrg. Des., 84 (1), pp 1-11 (Jan 1985) 14 figs, 3 refs

KEY WORDS: Tubes, Fluid-induced excitation

Equations are developed governing the stability of a fluid-conveying tube which is clamped at the upstream end and free at the other with a variable knife-edge support at some interior point. Using these quotations, the stability characteristics of such a configuration are analyzed numerically. The effect on stability response produced by a change in support position is described.

86-857
Some Remarks on the Oscillatory Pipe Flow
S. Tsangaris
National Technical University of Athens, Athens, Greece
Rev. Roumaine Sci. Tech., Mecanique Appl., 30 (4), pp 365-369 (July/Aug 1985) 4 figs, 3 refs

KEY WORDS: Pipes, Fluid-induced excitation

Some interesting aspects of the viscous flow due to an oscillating pressure gradient along a straight, circular pipe with rigid walls are discussed.

86-858
Moment-Rotation Relationship Considering Flattening of Pipe Due to Pipe Whip Loading
Shuzo Ueda
Japan Atomic Energy Research Inst., Tokai-mura, Naka-gun, Ibaraki-ken, Japan
Nucl. Engrg. Des., 85 (2), pp 251-259 (Mar 1985) 11 figs, 6 tables, 10 refs

KEY WORDS: Pipes, Nuclear power plants, Pipe whip

It is important to take flattening of pipe into consideration in order to obtain pipe deformation due to pipe whip loading. An experimental relationship between the flattening of pipe and the pipe surface strain was used to derive the moment-rotation relationship of whipping pipe. The derived moment-rotation relationship was used to calculate the pipe strain in the pipe whip tests using a simplified energy balance method.

86-859
Assessment of Coupling Effects of Coolers and Piping Systems
P. Kaas, W. Hollerbach

Kraftwerk Union, Offenbach am Main, Fed. Rep. Germany
Nucl. Engrg. Des., 84 (1), pp 13-19 (Jan 1985) 6 figs

KEY WORDS: Pipelines, Finite element technique

Linear elastic FEM calculations were carried out for both large joint (coupled) systems and decoupled subsystems. The resulting coupled and uncoupled loads at significant modal points are evaluated.

86-860
Earthquake and Aircraft Impact Simulation Testing of Piping Systems
E. Haas, J. Lockau, G. Müller
Kraftwerk Union AG, Offenbach/Main, Fed. Rep. Germany
Nucl. Engrg. Des., 85 (1), pp 25-29 (Feb 1985) 6 figs

KEY WORDS: Pipelines, Nuclear power plants, Seismic response, IMpact response, Crash research (aircraft)

Safety-related piping systems in nuclear power plants and their supports are usually designed and analyzed as linear elastic structures within elastic limits of material behavior. This applies for earthquake loads (SSE) and in Germany also for the external event of aircraft impact (AI). This load case with its extremely low probability and short duration is comparable in frequency content with internal shock loads. In order to define the conservativities of realistic systems designed in that way, at high SSE and AI load levels a large series of tests with different configurations were performed.

DUCTS

86-861
A Bidirectional Microphone for the Measurement of Duct Noise
R.F. La Fontaine, I.C. Shepherd, A. Cabelli
Commonwealth Scientific and Industrial Research Organization, Melbourne, Australia
J. Sound Vib., 101 (4), pp 565-573 (Aug 22, 1985) 7 figs, 5 refs

KEY WORDS: Ducts, Noise measurement

A bidirectional microphone which resolves acoustic plane waves in ducts into forward and backward propagating components is described. The microphone was a flat frequency response and finds applications in the analysis of duct noise and in the determination of reflection coefficients for various duct configurations. It can also be employed as a unidirectional microphone in active noise attenuators.

86-862
Noise and Air Consumption of Blow-Off Nozzles
B. Huang, E.I. Rivin
Ford Motor Company, Detroit, Michigan
S/V, Sound Vib., 19 (7), pp 26-33 (July 1985) 14 figs, 9 refs

KEY WORDS: Nozzles, Noise reduction

Blow-off nozzles are among the most intensive and annoying noise sources in a manufacturing facility. Several types of silencer nozzles were investigated in wide ranges of air pressure and thrust. Results of the investigation indicate that the multiple-jet and air-shroud nozzles given 3 to 10 dBA noise reduction over simple nozzles without significant increases in air consumption.

BUILDING COMPONENTS

86-863
Calculation of Shaping Machinery Vibration — Using Counter-Blow Hammer as an Example (Berechnung des Schwingungsverhaltens von Umformmaschinen —Beispiel: Gegenschlaghammer)
M. Weck, H.-D. Schöllhorn
Konstruktion, 37 (9), pp 349-354 (Sept 1985) 7 figs, 8 refs (in German)

KEY WORDS: Structural members, Design techniques

Using the counter-blow hammer as an example, the authors show that the vibration of complex structures can be determined in the design stage. Structural members and components are approximated from construction data by means of finite element networks. The calculations are performed only for the marked points on members or components representing vibration. The total model takes joints and their stiffness and damp-

ing characteristics into consideration. From these results the expected displacement and vibration of structural members can be determined.

86-864
The Influence of an Internal Resonance on Non-Linear Structural Vibrations Under Subharmonic Resonance Conditions
D.T. Mook, R.H. Plaut, N. HaQuang
Virginia Polytechnic Institute and State University, Blacksburg, Virginia
J. Sound Vib., 102 (4), pp 473-492 (Oct 22, 1985) 11 figs, 5 refs

KEY WORDS: Structural members, Internal resonance, Subharmonic oscillation

The response of structural elements to a simple harmonic, transverse excitation is considered. The effects of both initial curvature and mid-surface stretching are included; thus, the governing equations contain both quadratic and cubic terms. A perturbation technique, the method of multiple scales, is used to determine the response.

86-865
Floor Spectra for Nonclassically Damped Structures
M.P. Singh, A.M. Sharma
Virginia Polytechnic Inst. and State Univ., Blacksburg, VA
ASCE J. Struc. Engrg., 111 (11), pp 2446-2463 (Nov 1985) 5 figs, 2 tables, 18 refs

KEY WORDS: Floors, Seismic response spectra, Damped structures

An approach is presented for the generation of seismic floor response spectra for structures which cannot be modeled as classically damped. Although the nonclassically damped structures do not possess classical modes, the proposed approach can still employ prescribed ground response spectra directly as input for the generation of floor spectra. The approach requires the solution for a complex eigenvalue problem which provides the information about the equivalent modal frequencies and damping ratios of the structure. The floor response spectrum value is expressed in terms of these equivalent modal parameters.

86-866
Theory for Thermally Induced Roof Noise
C.H. Ellen, C.V. Tu, W.Y.D. Yuen
John Lysaght Ltd., Port Kembla, New South Wales, Australia
ASCE J. Struc. Engrg., 111 (11), pp 2302-2319 (Nov 1985) 4 figs, 1 table, 5 refs

KEY WORDS: Roofs, Temperature effects, Noise generation

This paper presents a theoretical analysis of thermally induced noise in sheet metal roofs A quasi-static model of the roof behavior is developed based on roof support batten frictional forces constraining the thermal expansion and contraction of the sheeting.

DYNAMIC ENVIRONMENT

ACOUSTIC EXCITATION

86-867
Scattering of Sound Waves by Inhomogeneities: Time Domain Analysis
R.D. Mountain, G. Birnbaum
National Bureau of Standards (NEL), Gaithersburg, MD
7 pp (1984) (Pub. Nondestructive Testing Communications 1, pp 219-225, 1984) PB85-202901

KEY WORDS: Sound waves, Wave scattering, Time domain method

The scattering of sound waves by isolated inhomogeneities in an otherwise uniform solid is analyzed using the Born approximation in the time domain. The volume and shape of the scatterer is related to time moments of the amplitude of the scattered signal. The matching of the incident pulse shape to the size of the scatterer is found to be essential if this type of measurement is to yield useful results.

86-868
Acoustic Normal Mode Propagation Through a Three-Dimensional Internal Wave Field
C. Penland
Applied Research Laboratories, Univ. of Texas at Austin, Austin, TX

J. Acoust. Soc. Amer., 78 (4), pp 1356-1365 (Oct 1985) 1 table, 16 refs

KEY WORDS: Sound waves, Normal modes, Wave propagation

In describing the effects of internal waves on acoustic normal modes excited by a time-harmonic point source, all previous descriptions have neglected the existence of azimuthal fluctuations in the acoustic field. This study compares this azimuthally symmetric case with the case where azimuthal fluctuations in the acoustic field are taken into account.

86-869

Sound Propagation Over a Sloping Bottom Using Rays with Beam Displacement

C.T. Tindle, G.B. Deane
Univ. of Auckland, Auckland, New Zealand

J. Acoust. Soc. Amer., 78 (4), pp 1366-1374 (Oct 1985) 8 figs, 11 refs

KEY WORDS: Underwater sound, Sound waves, Wave propagation

Ray theory with beam displacement has been shown previously to be an accurate method of finding the acoustic field at low frequencies in shallow water by comparison with normal mode solutions. The method is extended to the case of a uniformly sloping bottom. The extension requires only geometry and involves no approximations. It is not restricted to small angles.

86-870

Direct Acoustic Scattering for One-Dimensional Lossy Media

Jing Bai, C. Rorres, P.C. Pedersen, O.J. Tretiak
Drexel Univ., Philadelphia, PA

J. Acoust. Soc. Amer., 78 (4), pp 1375-1383 (Oct 1985) 10 figs, 33 refs

KEY WORDS: Sound waves, Wave scattering

The scattering of acoustic waves by inhomogeneities within a one-dimensional lossy medium is investigated. The inhomogeneities may be spatial variations in the attenuation coefficient of the lossy medium and/or variations in its density and wave velocity. The frequency dependence of the attenuation coefficient is modeled after loss mechanisms governed by viscosity, heat conduction, and single and multiple relaxation processes. Two methods previously developed for lossless media are extended to treat the determination of the reflection and transmission coefficients of an inhomogeneous lossy medium.

86-871

Wave Propagation in Ground-Structure Systems with Line Contact

D. Takahashi
Kyoto University, Kyoto, Japan

J. Sound Vib., 101 (4), pp 523-537 (Aug 22, 1985) 4 figs, 14 refs

KEY WORDS: Soil-structure interaction, Wave Propagation, Sound waves

The response of a structure in contact with the surface of a viscoelastic half-space (VEHS) is considered. The system is modeled as a ground-structure system. Vibration and radiation of sound into the closed space of the structure, resulting from a harmonic line force applied on the surface of the VEHS, are investigated theoretically.

86-872

Hydrodynamic Noise and Surface Compliance — An Overview of the Naval Underwater Systems Center IR/IED Program

H. Bakewell, W.A. Von Winkle
Naval Underwater Systems Ctr., New London, CT

Rept. NO. NUSC/TM-851080, 38 pp (May 15, 1985) AD-A157 799/8/GAR

KEY WORDS: Hydrodynamic excitation, Noise generation

An independent research and exploratory development program on compliant surfaces is investigating turbulent flows over compliant layers to determine whether a class or classes of such layers can be devised for control and reduction of hydrodynamic (flow) noise. The coupled fluid/elastic problem to characterize the flow/layer interactions, resultant effects on the turbulent velocity components and effects both at the surface and within the layer are discussed.

86-873

Nearfield Acoustic Holography: I. Theory of Generalized Holography and the Development of NAH

J.D. Maynard, E.G. Williams, Y. Lee

Pennsylvania State Univ., University Park, PA
J. Acoust. Soc. Amer., 78 (4), pp 1395-1413 (Oct 1985) 14 figs, 31 refs

KEY WORDS: Acoustic holography

The fundamental principles of holography are reviewed, and a sound radiation measurement system, called nearfield acoustic holography (NAH), which fully exploits the fundamental principles, is described.

SHOCK EXCITATION

86-874

Variational Principle for Penetrator Dynamics Using Bilinear Functional and Adjoint Formulation

C.N. Shen
Army Armament Res. and Dev. Ctr., Watervliet, NY
(Trans. Army Conf. Appl. Mathematics and Computing (2nd), Washington, DC, May 22-25, 1984, AD-A154 047, pp 185-197) AD-P004 915/5/GAR

KEY WORDS: Projectile penetration, Variational methods

The solution problems in both spatial and time domains using the finite element method can be based on the variational principle employing bilinear functional and adjoint formulation. This principle is extended to coupling systems in matrix vector form such as penetration dynamics. The present hyperbolic type partial differential equation or interest has two dependent and two independent variables with the coupling in the spatial domain.

86-875

Performance and Predictions for a Large Blast Simulator Model

D.M. Hisley, E.J. Gion, B.P. Bertrand
Army Ballistic Res. Lab., Aberdeen Proving Ground, MD
Rept. No. BRL-TR-2647, 65 pp (Apr 1985) AD-A158 080/2/GAR

KEY WORDS: Shock tube testing, Test facilities

An attempt is made to verify the predictions from a I-D BRL Code against the flow from a complicated, nonstraight shock tube configuration; the code then could be utilized for future large blast/thermal simulator (LB/TS) design and prediction of performance.

86-876

Simplified Design of Components and Systems Against Aircraft Crash Induced Loads Using Verified Response Spectra

N.J. Krutzik
Kraftwerk Union AG, Offenbach/Main, Fed. Rep. Germany
Nucl. Engrg. Des., 85 (1), pp 59-63 (Feb 1985) 7 figs, 5 refs

KEY WORDS: Impact response, Mechanical components, Electric components, Crash research (aircraft)

The progress which has been achieved in the application of the assumptions used to define relevant aircraft impact responses for the design of mechanical and electrical components and systems installed inside buildings for practical needs has led to a notable reduction in analytical calculation effort on the side of both the analyst and the reviewer. A simplified quasi-static design procedure to be introduced for all components installed inside buildings is presented.

86-877

Computer Simulation of the Effect of Free Surface Reflection on Shock Wave Propagation in Water

M. Kamegai, L.S. Klein, C.E. Rosenkilde
Lawrence Livermore National Lab., CA
Rept. No. UCRL-92080, CONF-850736-23, 7 pp (July 1985) (American Phys. Soc. topical conf. on shock waves in condensed matter, Spokane, WA, July 22, 1985) DE85014807/GAR

KEY WORDS: Underwater shock waves, Wave propagation, Computerized simulation

A computer simulation is used to study the behavior of a fluid which has been set into motion by a point explosion below a bounding free surface. Of particular interest is the interaction between the incident shock wave and the reflected rarefaction signal which, under certain conditions, can overtake the shock front. Onset

criteria for the envelope which separates the region of irregular from that of regular rarefaction, the nonspherical shape of the shock front, and the pulse profile for several depths of burst covering both strong and weak shock interactions with the surface are discussed.

86-878

Analysis of the Spatial Variation of Seismic Waves and Ground Movements from Smart-1 Array Data

Chin-Hsiung Loh
National Central University, Taiwan, R.O.C.

Earthquake Engrg. Struc. Dynam., 13 (5), pp 561-581 (Sept/Oct 1985) 26 figs, 19 refs

KEY WORDS: Seismic response, Damage prediction

Specially designed arrays of strong motion seismographs located near earthquake sources are required for engineering studies of the near-source properties and the spatial variation of seismic waves. The SMART-1 array in Taiwan which provides good records for this type of study is described.

86-879

Shock-Wave Propagation in Gas Mixtures by Means of a Discrete Velocity Model of the Boltzmann Equation

R. Monaco
Dip. di Matematica Politecnico di Torino, Torino, Italy

Acta Mech., 55, pp 239-251 (July 1985) 3 figs, 3 tables, 14 refs

KEY WORDS: Shock wave propagation

The shock-wave propagation problem for a binary gas mixture is studied by means of a 12-discrete velocity model of the Boltzmann equation. From a mathematical standpoint the problem consists of solving a set of six ordinary nonlinear differential equations with limit conditions. The solution is found in an approximated analytical form expressed by an expansion in Lengendre polynomials.

VIBRATION EXCITATION

86-880

Study of the Effect of an Oscillating Wall Protuberance on the Surrounding Aerodynamic Field

O. Rodriguez, J.M. Desse
Institut de Mecanique des Fluides de Lille, France

Rept. No. IMFL-84/49, 71 pp (Nov 12, 1984) PB85-237485/GAR (in French)

KEY WORDS: Spoilers, Aerodynamic stability, Periodic excitation, Fluid-induced excitation

The study is done within the general framework of unstable aerodynamic control research. It studies the local aerodynamic response of a spoiler undergoing a sinusoidal oscillation. The objective of this study was the realization of a basic experiment around a simplified geometry, in view of obtaining an accurate description of the phenomenon and trying to understand the mechanism.

86-881

Describing Function Analysis of Density Wave Oscillations

Shaw-Cuang Lee

Ph.D. Thesis, Univ. of Michigan, 383 pp (1984) DA8502871

KEY WORDS: Nonlinear systems, Frequency domain method, Fluids, Functional analysis

Density-wave oscillation (DWO) is a form of low-frequency flow instability that can occur in all the two-phase flow systems satisfying a constant pressure-drop boundary condition. In this thesis, DWOs are investigated using the describing function method, which extends the linear frequency-domain analysis to nonlinear systems, yielding information on the frequency and magnitude of periodic oscillations, or limit-cycles, that can occur in nonlinear systems. The proposed nonlinear model for the DWO considers only those nonlinearities that enter the calculation of the pressure drops in terms of flow velocity and density variations, in the implementation of constant pressure-drop boundary conditions.

86-882
Control of Dynamic Systems by Modal Energy Reallocation
Chung Lun Wong
Ph.D. Thesis, Univ. of California, Los Angeles, CA, 159 pp (1984) DA8505686

KEY WORDS: Vibration control, Modal energy reallocation method

Vibration suppression and control can be achieved in many ways. Many methods are based on the concept of state variable feedback using information from sensors and actuators strategically placed on the system to be controlled. This dissertation deals with a concept of controlling vibrational energy by reallocating modal energies between desirable and undesirable modes. This reallocation is affected by a unique and simple scheme using the application (and subsequent removal) of constraints to the vibrating system. This constraint can be applied such that no work is done on the system, but will result in a definite reshuffling of energies between modes; e.g., from undesirable to desirable ones.

86-883
A Catastrophe Theory Description of Stick-Slip Motion in Sliding
B.E. Klamecki
Univ. of New Mexico, Albuquerque, NM
Wear, 101 (4), pp 325-332 (Feb 15, 1985) 6 figs, 5 refs

KEY WORDS: Stick-slip response

Stick-slip motion is analyzed by studying structural changes in the mathematical model describing sliding friction. The sliding system is assumed to operate in a way which minimizes energy input to the system. For an exponential dependence of friction force on sliding velocity, the system sliding behavior is multivalued for some ranges of values of the system parameters. The effect of different parameter values on system behavior is illustrated and results of this investigation are compared with a published steady sliding criterion.

86-884
The Method of Fundamental Solutions. The Theory of Thick Oscillatory Airfoil in Subsonic Flow
L. Dragos
Univ. of Bucharest
Rev. Roumaine Sci. Tech., Mecanique Appl., 29 (6), pp 555-568 (Nov/Dec 1984) 11 refs

KEY WORDS: Airfoils, Fluid-induced excitation

The method of fundamental solutions is applied to the theory of two-dimensional oscillatory airfoil in subsonic flow. The integral Possio's equation is obtained and its solution for slow oscillations is given. Explicit formulae for lift and momentum of momentum are obtained. The theory of incompressible fluids is presented.

MECHANICAL PROPERTIES

DAMPING

86-885
Average Loss Factors for Use in Statistical Energy Analysis
K.T. Brown, B.L. Clarkson
University College of Swansea, Wales, UK
(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, AD-A152 547, pp BB-1 - BB-13) AD-P004 710/0/GAR

KEY WORDS: Energy dissipation, Loss factor, Statistical energy methods

This paper describes a new technique for the measurement of frequency band and space averages loss factors of uniform structural components. Values are obtained by an energy measurement technique which is shown to give good results over a wide range of loss factor values. The results obtained can be used in statistical energy analysis prediction programs, or simply to study the frequency dependence of loss factors in components or materials.

86-886
Conservation Laws for Dissipative Systems Possessing Classical Normal Modes
L.Y. Bahar, H.G. Kwatny
Drexel University, Philadelphia, PA
J. Sound Vib., 102 (4), pp 551-562 (Oct 22, 1985) 1 fig, 14 refs

KEY WORDS: Damped systems, Energy dissipation

Linear viscously damped dynamical systems whose matrix coefficients satisfy a certain commutativity condition are known to exhibit the same normal modes as the ones associated with the same system in the absence of damping. Such dissipative systems are said to possess classical normal modes. It is shown that the original equation of motion in the displacement vector which exhibits velocity coupling can be transformed into an equation where the velocity term is no longer present, but whose matrix coefficients are time-dependent. A commutativity condition further reduces the resulting equation into one with constant coefficients.

86-887

On Damped Non-Linear Dynamic Systems with Many Degrees of Freedom

Cheng-Ching Chi, R.M. Rosenberg
Univ. of California, Berkeley, CA

Intl. J. Nonlin. Mech., 20 (5/6), pp 371-384 (1985) 4 figs, 10 refs

KEY WORDS: Multidegree of freedom systems, Nonlinear systems, Damped structures

Nonlinear mass-spring-damper systems with many degrees of freedom are studied; all springs and/or all dampers may be strongly nonlinear. It is shown that the ultimate state of completely damped systems is always rest; that of incompletely damped systems may be either rest or a periodic normal mode motion.

86-888

Variable Force, Eddy-Current or Magnetic Damper

R.E. Cunningham
NASA Lewis Res. Ctr., Cleveland, OH

U.S. PATENT-4 517 505, 6 pp (May 14, 1985)

KEY WORDS: Dampers, Resonant frequencies, Rotating structures

An object of the invention is to provide variable damping for resonant vibrations which may occur at different rotational speeds in the range of rpms in which a rotating machine is operated. A variable force damper in accordance with the invention includes a rotating mass carried on a shaft which is supported by a bearing in a resilient cage.

86-889

Steady-State Dynamic Analysis of Hysteretic Systems

D. Capecchi, F. Vestroni
Istituto di Scienza delle Costruzioni, L'Aquila, Italy

ASCE J. Engrg. Mech., 111 (12), pp 1515-1531 (Dec 1985) 14 figs, 1 table, 14 refs

KEY WORDS: Periodic excitation, Hysteretic damping

A great many hysteretic models have been recently introduced in the analysis of dynamic behavior of structures and structural elements. This paper considers the steady-state oscillations of single-degree-of-freedom systems with different force-deflection relationships. Three types of constitutive laws are covered: bilinear, stiffness, degrading, and stiffness-strength degrading.

86-890

On the Reliability of a Simple Hysteretic System

B.F. Spencer, Jr., L.A. Bergman
Univ. of Notre Dame, Notre Dame, IN

ASCE J. Engrg. Mech., 111 (12), pp 1502-1514 (Dec 1985) 9 figs, 1 table, 20 refs

KEY WORDS: Hysteretic damping

A method to determine statistical moments of time to first passage of a simple oscillator, incorporating the modified Bouc hysteresis model, has been developed. The accuracy and economy of the method is demonstrated for a particular example drawn from base isolation of a simple structure. A comparison of the finite element results with those obtained by Monte Carlo simulation is presented.

86-891

Periodic Response of Yielding Oscillators

A. DebChaudhury
Univ. of Illinois at Chicago, Chicago, IL

ASCE J. Engrg. Mech., 111 (8), pp 977-994 (Aug 1985) 13 figs, 17 refs

KEY WORDS: Oscillators, Harmonic response, Hysteretic damping

A new method is employed to obtain the response of a general yielding oscillator to harmonic excitation. This method can be applied to

a wide range of hysteretic systems, once the skeleton curve and the loop is defined. In this paper, responses are obtained for four different models, describing the hysteretic behavior of a physical system. The analytical expressions for the frequency response curves and the frequency shift at peak responses are obtained. Results are compared with the numerical solutions and the findings of earlier investigators.

86-892
Random Vibration of Degrading, Pinching Systems
T.T. Baber, M.N. Noori
Univ. of Virginia, Charlottesville, VA
ASCE J. Engrg. Mech., 111 (8), pp 1010-1026 (Aug 1985) 17 figs, 17 refs

KEY WORDS: Hysteretic damping, Random vibration

A differential equation model to describe pinching, degrading response of hysteretic elements is presented. The model consists of a nonpinching hysteretic element, in series with a "slip-lock" element. Zero mean response statistics for a single degree of freedom oscillator whose stiffness is described by the series model, computed by equivalent linearization and by Monte Carlo simulation, are compared.

86-893
Vibrations Isolation of an Elevator System
H.S. Tzou, A.J. Schiff
North Carolina Agricultural and Technical State Univ., Greensboro, NC
(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, AD-A152 547, pp LL-1 - LL-6) AD-P004 718/3/GAR

KEY WORDS: Elevators, Viscoelastic damping, Seismic design

The vulnerability of an elevator system has been demonstrated from recent earthquake reports. An elevator counterweight/frame/guide rails system is modeled by beam, finite elements. Because of large structural vibration, parts of the system may come in contact if their relative displacement exceeds the gap. Due to the fact that large dynamic force resulting from contact often causes the damage of the elevator system, the study of viscoelastic damper being used as vibration isolator is introduced. A system with viscoelastic dampers which are modeled by standard linear model is evaluated in the dynamic analysis.

86-894
Structural Damping Potential of Waveguide Absorbers
E.E. Ungar, L.G. Kurzweil
Bolt Baranek and Newman, Inc., Cambridge, MA
(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, AD-A152 547, pp CC-1 - CC -15) AD-P004 711/8/GAR

KEY WORDS: Waveguide absorbers, Vibration control, Damping coefficients

Results of a preliminary study indicate that waveguide absorbers -- structural elements that extract energy from vibrating structures in the form of traveling waves -- may serve as effective vibration reduction means. Expressions are presented that indicate how the damping effectivenesses of waveguide absorbers attached to structures depend on absorber and structural parameters. Realizations of waveguide absorbers in terms of damped tapered rods and beams are described.

86-895
Damping Measurement by Dynamic Stiffness Methods
D.I.G. Jones, A. Muszynska
Air Force Materials Lab., Wright-Patterson AFB, OH
(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, AD-A152 547, pp X-1 - X-26) AD-P004 706/8/GAR

KEY WORDS: Damping coefficients, Dynamic stiffness

The problem of determining the mass, stiffness and damping parameters of a structure from measured modal response data is addressed. Two examples, one from dynamics of a discrete structure and the other for a rotor-bearing system, illustrate the methodology.

86-896
Analysis of a Self-Excited System with Dry Friction
A. Tondl

National Research Institute for Machine Design, Prague, Czechoslovakia
Intl. J. Nonlin. Mech., 20 (5/6), pp 471-479 (1985) 12 figs, 7 refs

KEY WORDS: Fluid-induced excitation, Coulomb friction

A new approach to the modeling of systems in flow-induced self-excitation is presented. An elastically supported body situated in a channel carrying a flowing medium is analyzed and the effect of additional dry friction is investigated.

86-897
Friction Damping Studies at Imperial College
C.F. Beards
Imperial College of Science and Technology, London, UK
(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, AD-A152 547, pp N-1 - N-7) AD-P004 697/9/GAR

KEY WORDS: Joints, Coulomb friction

Force transfer by friction between joint elements, energy dissipation mechanisms, friction damping in joints and the effects of increased joint damping on the vibration response of structures are discussed.

86-898
Characteristics of Dry Friction Damping
A.V. Srinivasan, B.N. Cassenti, D.G. Cutts
United Technologies Res. Ctr., East Hartford, CT
(Vibr. Damping Workshop Proc., Long Beach, CA, Feb 27-29, 1984, AD-A152 547, pp 1-1 -1-31) AD-P004 693/8/GAR

KEY WORDS: Coulomb friction

A summary of a literature survey pertaining to the overall problem of estimating damping due to dry friction forces induced at interfaces of vibrating components is presented. The survey clearly indicates the complex processes involved during rubbing of one component relative to another bringing into play a host of parameters.

FATIGUE

86-899
The Influence of Residual Stresses Induced by Plastic Deformation on Rolling Contact Fatigue
S. Cretu, N.G. Popinceanu
Jassy Polytechnic Institute, Jassy Romania
Wear, 105 (2), pp 153-170 (Sept 16, 1985) 15 figs, 2 tables, 36 refs

KEY WORDS: Fatigue life, Rolling friction

A general method is described for finding the optimum residual stress distribution. Cylindrical test specimens were subjected to a prestress cycle which was able to induce a favorable residual stress distribution, after which the specimens were fatigue tested.

86-900
Strain Energy Density Criteria for Dynamic Fracture and Dynamic Crack Branching
M. Ramulu, A.S. Kobayashi
Univ. of Washington, Seattle, WA
Rept. No. UWA/DME/TR-85/51, 24 pp (July 1984) AD-A157 914/3/GAR

KEY WORDS: Crack propagation, Fracture properties

Dynamic extension of Sih's fracture criterion is used to analyze dynamic crack propagation and branching. Influence of the nonsingular components, which are known as the higher order terms in the crack tip stress field, on the strain energy density distribution at a critical distance surrounding the crack tip moving at constant crack velocity is examined.

86-901
A Fatigue-Testing Device for Elastomeric Adhesives and Sealants
L.B. Sandberg
Michigan Technological Univ., Houghton, MI
Exptl. Tech., 9 (10), pp 28-29 (Oct 1985) 4 figs

KEY WORDS: Fatigue tests, Test equipment, Adhesives, Joints, Seals

A small low-cost machine designed specifically for fatigue testing of structural sealant joints which are exposed to cyclic loadings by wind forces and thermal movements is described. The machine is capable of testing small delicate specimens at a constant load and displacement cycle. It includes a full reversal cycle, automatic shut off and slow operating speeds. The device uses gravity to supply load.

86-902
The Driving Force for Mode II Crack Growth Under Rolling Contact
S.D. O'Regan, G.T. Hahn, C.A. Rubin
Vanderbilt University, Nashville, TN
Wear, 101 (4), pp 333-346 (Feb 15, 1985) 5 figs, 1 table, 12 refs

KEY WORDS: Fatigue life, Rolling friction

The driving force for the cyclic growth of small subsurface cracks subjected to repeated rolling contact is evaluated. The calculations take into account the elastic contact stresses, the friction resisting the mode II sliding of the crack faces, and the residual circumferential tensile and compressive stresses produced by plastic deformations close to the rim.

EXPERIMENTATION

MEASUREMENT AND ANALYSIS

86-903
Dynamic Determination of Pile Capacity
F. Rausche, G.G. Goble, G.E. Likins, Jr.
Goble, Rausche, Likins and Assoc., Inc., Warrensville Heights, OH
ASCE J. Geotech. Engrg., 111 (3), pp 367-383 (Mar 1985) 9 figs, 1 table, 18 refs

KEY WORDS: Measurement techniques, Pile structures, Force measurement, Acceleration measurement

A method is presented for determining the axial static pile capacity from dynamic measurements of force and acceleration made under the impact of a large hammer. The basic equation for calculation of the forces resisting pile penetration is derived. The limitations of the basic resistance equation are discussed and illustrative examples of field measurements are given.

86-904
Multiple-Input Experimental Modal Analysis
R.J. Allemang, D.L. Brown
Univ. of Cincinnati, Cincinnati, OH
Exptl. Tech., 9 (10), pp 16s-23s (Oct 1985) 79 refs

KEY WORDS: Experimental modal analysis, Multipoint excitation techniques

The technology of experimental modal analysis is expanding rapidly as the impact of multiple inputs, or references, is being realized. This paper traces the development of experimental-modal-analysis techniques while noting this current trend toward multiple-input utilization in the estimation of system parameters.

86-905
Signal Processing and the Fast-Fourier-Transform (FFT) Analyzer
L.D. Mitchell
Virginia Polytechnic Inst. and State Univ., Blacksburg, VA
Exptl. Tech., 9 (10), pp 3s-15s (Oct 1985) 8 figs, 10 refs

KEY WORDS: Modal analysis, Fast Fourier transform, Signal processing techniques, Frequency analyzers

Use of fast-Fourier-transform (FFT) techniques in the analysis of experimental dynamic data for the purpose of the identification of the physical characteristics of the measured system is studied. Consideration is given to transducer and system calibration, signal conditioning, the relationship of sample rate to frequency range, anti-aliasing filter processes, time-domain windows and their data-leakage effects, channel-to-channel crosstalk, various algorithms for computing frequency-response function, and the coherence function.

86-906
Structural Modification and Modal Analyses
V.W. Snyder
Michigan Technological Univ., Houghton, MI
Exptl. Tech., 9 (10), pp 24s-31s (Oct 1985) 8 tables, 16 refs

KEY WORDS: Modal analysis, Substructuring methods, Structural modification techniques

The mechanism for the determination of dynamic characteristics of linear systems which has been modified is discussed. The mechanism can be used to marry both analytical and experimental techniques. A method is presented which permits a very logical substructuring to be performed. The modification technique uses the solution already available to find the solution to the modified or combined structure in a fast and efficient manner. The technique is effective on systems with complex eigenvalues and eigenvectors.

86-907
Dynamic Analysis of Structures by the DFT Method
A.S. Veletsos, C.E. Ventura
Rice Univ., Houston, TX
ASCE J. Struc. Engrg., 111 (12), pp 2625-2642 (Dec 1985) 11 figs, 3 tables, 9 refs

KEY WORDS: Discrete Fourier transform, Linear systems

Following a brief review of the discrete Fourier transform (DFT) method of analyzing the dynamic response of linear structures, the limitations and principal sources of potential inaccuracies of this approach are identified, and an evaluation is made of the nature and magnitudes of the errors that may result. Two versions of a modification are then presented which dramatically improve the efficiency of the DFT procedure, and the relative merits of the two techniques are examined.

DYNAMIC TESTS

86-908
SAMSON — A Vibration Test Facility for Simulating Multi-Axis Dynamic Motion
A. Kleine-Tebbe
Hoch-temperatur-Reaktorbau, GmbH, Fed. Rep. Germany
Brown Boveri Rev., 72 (4), pp 205-209 (April 1985) 6 figs, 2 tables

KEY WORDS: Vibration tests, Test facilities

SAMSON (Simulation Apparatus for Modeling Seismic Oscillations of Nuclear components) is used to verify the safe functioning of large components (max. static load 40 t) under dynamic load conditions. Components which can be tested using this facility range from switchboards, large fittings and plant equipment to entire machines.

86-909
Sample Size Effect on Dynamic Properties of Sand in the Simple Shear Test
M.I.M. Amer
Ph.D. Thesis, Univ. of Maryland, 772 pp (1984) DA8506486

KEY WORDS: Testing techniques, Soils, Shear modulus, Damping coefficients

In the last few years, cyclic simple shear testing has been analyzed experimentally and theoretically and the advantages and limitations of the test presented. The main drawback concerns the sample size, in that for a small sized sample, the test results are affected by the nonuniformity of the stress in the sample. A comprehensive experimental program undertaken to investigate the sample size effect on the primary dynamic soil properties; namely the shear modulus and damping is described.

86-910
Opening a Pandora's Box: One Shaker is Never Enough
W. Tustin
Tustin Inst. of Technology, Santa Barbara, CA
Test, 47 (6), pp 18-20 (Dec/Jan 1985-86) 4 figs

KEY WORDS: Shakers, Test equipment

This paper discusses the selection and purchase of shakers along with their applications to environmental testing.

86-911
Accelerated Vibration Durability Testing: A Practical Approach
G.A. Shinkle
General Motors Corp.
SAE Paper No. 840501

KEY WORDS: Vibration tests, Testing

Accelerated laboratory testing procedures permit studies of components and their failures without the delays associated with field testing.

SCALING AND MODELING

86-912
Dynamic Centrifugal Modeling of a Horizontal Dry Sand Layer
P.C. Lambe, R.V. Whitman
North Carolina State Univ., Raleigh, NC
ASCE J. Geotech. Engrg., 111 (3), pp 265-287 (Mar 1985) 16 figs, 3 tables, 15 refs

KEY WORDS: Sand, Layered materials, Test models

The dynamic response of a 10.7 m (35 ft.) thick dry sand layer was modeled on the Cambridge University centrifuge at scale factors of 35 and 80. A stack of teflon-coated aluminum rings and a latex membrane confined a cylindrically shaped sane model that has a height-to-diameter ratio equal to 1. During the scaled sinusoidal base shaking, electronic transducers measured accelerations, transient horizontal displacements and surface settlements. Measured results were used to evaluate scaling laws governing dynamic centrifugal modeling and to test for consistency with results of numerical methods and laboratory tests reported in the literature.

DIAGNOSTICS

86-913

Machinery Problem Diagnosis Using Finite Element Methods

J.M. Steele

Stress Technology Inc., Rochester, NY

S/V Sound Vib., 19 (9), pp 26-29 (Sept 1985) 6 figs

KEY WORDS: Diagnostic techniques, Finite element technique, Steam turbines, Disks

A methodology is presented which uses finite element analysis as the focal point for diagnosing and determining a fix for machinery problems. The methodology is presented as a five-step procedure. A case study of a cracked steam turbine disk is given as an example.

86-914

Diagnosing Machinery Problems With Automated Vibration Analysis

C.K. Janisz, R.E. Brokenshire

BEAR Associates, Royal Oak, MI

S/V Sound Vib., 19 (9), pp 14-17 (Sept 1985) 6 figs

KEY WORDS: Diagnostic techniques, Vibration analysers, Fossil power plants, Computer programs, Rotating machinery

A computer controlled automatic vibration analysis system is currently being used to monitor 28 machine trains at a 3200 megawatt, fossil fueled power plant. The system utilized permanent transducers mounted on rotating machinery, in-plant data analysis, and out-of-plant data storage and analysis.

MONITORING

86-915

Acoustic Emission for On-Line Reactor Monitoring: Results of Intermediate Vessel Test Monitoring and Reactor Hot Functional Testing

P.H. Hutton, R.J. Kurtz

Pacific Northwest Laboratory, Richland, WA

Nucl. Engrg. Des., 86 (1), pp 3-11 (Apr 1985) 13 figs, 1 table, 2 refs

KEY WORDS: Monitoring techniques, Acoustic emission, Crack detection, Crack propagation, Nuclear reactors

A program designed to develop the use of acoustic emission (AE) methods for continuous surveillance to detect and evaluate flaw growth in reactor pressure boundaries is discussed. Technology developed in the laboratory for identifying AE from crack growth and for using that AE information to estimate flaw severity is now being evaluated on an intermediate vessel test and on a reactor facility.

86-916

Monitoring Tool Wear During Wood Machining with Acoustic Emission

R.L. Lemaster, L.B. Tee, D.A. Dornfeld

University of California, Richmond, CA

Wear, 101 (3), pp 273-282 (Feb 1, 1985) 8 figs, 1 table, 12 refs

KEY WORDS: Monitoring techniques, Acoustic emission, Machine tools

The purpose of this study was to determine the degree of change in acoustic emission (AE) during cutting as a cutter tool was worn. Previous work has shown that AE is sensitive to changes in the chip formation process and therefore could be used to monitor continuously the state of the cutting process.

86-917

The Tribovibroacoustical Model of Machines

Cz. Cempel

Technical University of Poznán, Poznán, Poland

Wear, 105 (3), pp 297-305 (Oct 1, 1985) 2 figs, 2 tables, 9 refs

KEY WORDS: Monitoring techniques

The combined properties of wear and vibroacoustical processes are considered. This enables the creation of a new tribovibroacoustical model of machines which can be used for the evaluation and optimization of the mean time between failure or the breakdown time. This can also be used successfully for the prediction of the vibration amplitude and the condition of machinery at the running stage of its life as well as for breakdown time estimation.

86-918

On the Neutron Noise Diagnostics of Pressurized Water Reactor Control Rod Vibrations II. Stochastic Vibrations

I. Pázsit, O. Glöckler

Central Research Institute for Physics, Budapest, Hungary

Nucl. Sci. Engrg., 88 (1), pp 77-87 (Sept 1984)

KEY WORDS: Monitoring techniques, Rods, Fluid-induced excitation, Nuclear fuel elements, Stochastic processes

In an earlier publication, using the theory of neutron fluctuations induced by a vibrating control rod, a complete formal solution of rod vibration diagnostics based on neutron noise measurements was given in terms of Fourier-transformed neutron detector time signals. The suggested procedure was checked in numerical simulation tests where only periodic vibrations could be considered. The procedure and its numerical testing are elaborated for stochastic two-dimensional vibrations.

86-919

Data Management System for Predictive Maintenance Programs

R.L. Remillard

Structural Measurement Systems, San Jose, CA

S/V Sound Vib., 19 (9), pp 20-24 (Sept 1985) 11 figs, 4 refs

KEY WORDS: Monitoring techniques

This article describes how the Parameter Manager™, a new data management system, can be used to store and manipulate data acquired as part of an on-condition or predictive machinery maintenance program. The Parameter Manager is introduced as an easy-to-use, graphically-oriented system, which can be used to schedule monitoring activities and analyze acquired data to identify potential problems and trends.

86-920

Vibration Monitoring of Large Vertical Pumps Via A Remote Satellite Station

S.A. Cook, R.D. Crowe, S.P. Roblyer, H. Toffer

UNC Nuclear Industries, Inc., Richland, WA

Rept. No. UNI-SA-143, Conf-850926-3, 10 pp (Mar 21, 1985) ASME Vibr. and Sound Conf., Cincinnati, OH, Sept 10, 1985, DE85011701/GAR

KEY WORDS: Monitoring techniques, Pumps, Nuclear reactor components

A nuclear reactor with a unique design in which equipment such as pumps, turbines, generators and diesel engines are located in separate buildings, has led to the conclusion that the most cost-effective implementation of a dedicated vibration monitoring system would be to install a computerized network system in lieu of a single analyzing station. In the approach, semi-autonomous micro processor based data collection stations referred to as satellite stations are located near each concentration of machinery to be monitored. The satellite station associated with large vertical pumps vibration monitoring is described.

ANALYSIS AND DESIGN

ANALYTICAL METHODS

86-921

Love-Type Waves in a Randomly Non-Homogeneous Layer Over a Homogeneous Half-Space

Z. Hryniewicz

Technical University, Kos'alin, Poland

J. Sound Vib., 101 (4), pp 489-493 (Aug 22, 1985) 9 refs

KEY WORDS: Wave propagation, Elastic waves

The analysis deals with the Love wave propagation problem for an elastic half-space with a superficial layer the material properties of which are random functions. The solution for the dispersion equation and the average displacement are presented in the form of mathematical expressions. The method used is that of Karal and Keller, and is based on the Bourret approximation.

86-922
Subharmonic Oscillations in Three-Phase Circuits
K. Okumura, A. Kishima
Kyoto Univ., Japan
Intl. J. Nonlin. Mech., 20 (5/6), pp 427-438 (1985) 7 figs, 13 refs

KEY WORDS: Subharmonic oscillations

This paper analyzes the subharmonic oscillations generated in three-phase circuits by the asymptotic method.

86-923
Forced Oscillations of Systems with Impulse Force
Yu. A. Mitropolsky, A.M. Samoilenko
Ukrainian Academy of Sciences, Kiev, USSR
Intl. J. Nonlin. Mech., 20 (5/6), pp 419-426 (1985) 2 refs

KEY WORDS: Impact excitation, Forced vibrations

Using the method of averaging, the system of forced impact oscillation is investigated. Periodic solution of the system considered and first approximation of the averaged system are shown to exist.

86-924
Interspectral Combination Type Resonances of Nonlinear Conservative/Nonconservative Distributed Parameter Vibratory Systems
J. Padovan
University of Akron, Akron, OH
J. Franklin Inst., 319 (6), pp 521-542 (June 1985) 6 figs, 23 refs

KEY WORDS: Continuous parameter method, Harmonic excitation

The properties/formation of combination type resonances of nonlinear conservative/nonconservative distributed parameter vibratory systems subject to external harmonic inputs containing a profusion of frequencies are investigated. This includes the evaluation of simultaneously excited harmonic, sub/superharmonics as well as combination harmonics created by interactions between external and interspectral system frequency branches. A nonlinear nonconservative version of the wave equation which is excited by complex external harmonic fields is given detailed considerations.

86-925
Two Extremum Theorems Applicable to Stability Analyses of a Mechanical System
R. Parnes
Tel-Aviv Univ., Tel-Aviv, Israel
J. Franklin Inst., 319 (6), pp 543-547 (June 1985) 2 figs, 2 refs

KEY WORDS: Mechanical systems, Stability, Extremum principles

Two mathematical theorems and their proofs, applicable to stability investigations of mechanical systems, are presented. The theorems permit a determination of the stability of systems undergoing large displacements by means of a defined extremum function and without recourse to a study of higher variations of the total potential. An application to a simple mechanical system with one degree of freedom is given.

86-926
Model Reduction for a Class of Linear Dynamic Systems
F.F. Shoji, K. Abe, H. Takeda
Jobu University, Isesaki, Gumma, Japan
J. Franklin Inst., 319 (6), pp 549-558 (June 1985) 1 fig, 1 table, 12 refs

KEY WORDS: Reduction methods

In this paper, a model reduction technique to remedy the singularity of reduced-order models is proposed. The approach adopted is based on the least-square fitting of time-moments of the system. The proposed method is also available to stabilize unstable reduced models. This method is superior to existing techniques.

86-927
Model Reduction for Control Systems with Restricted Complexity Controllers
A. Lepschy, U. Viaro
Universita di Padova, Padova, Italy
J. Franklin Inst., 319 (6), pp 559-567 (June 1985) 1 fig, 1 table, 18 refs

KEY WORDS: Reduction methods, Frequency response

The problem of reduced-order modeling is considered in connection with the design of restricted complexity controllers. The suggested reduction method develops in two phases: a

simple frequency response of the overall feedback control system is determined according to the design specifications, and a reduced-order transference of the controlled plant is obtained by solving a linear set of equations in such a way that its behavior approximates that of the original plant at frequencies which are meaningful for the overall transfer function derived in the first step.

86-928
Dynamics of a Class of Repeated Systems with Non-identical Elastic and Visco-elastic Interconnections — a Bond Graph Approach
B. Samanta, A. Mukherjee
Indian Institute of Technology, Kharagpur, India
J. Franklin Inst., 319 (5), pp 473-497 (May 1985) 13 figs, 1 table, 9 refs

KEY WORDS: Periodic structures, Bond graph technique

Dynamics of a class of repeated systems, termed here "parallel" systems, are studied. The governing equations for such systems are derived in state-space form using bond graph techniques. An algorithm is established to decouple these otherwise coupled system equations so that the overall system dynamics can be studied with the same computational effort necessary in analyzing a single subsystem. The procedure is illustrated by a numerical example.

86-929
Estimating Eigenvalues for a Class of Dynamic Systems
A. Zeid, R. Rosenberg
Wayne State University, Detroit, MI
J. Franklin Inst., 320 (1), pp 21-40 (July 1985) 10 figs, 10 refs

KEY WORDS: Eigenvalue problems, Bond graph technique

In a previous work an approach was presented for extracting information about the eigenvalues of a linear, time-invariant dynamic system directly from a graphical model. in this paper a generalization is given of the results previously obtained. When suitably automated, the results obtained here can provide a considerable reduction in the computational effort required to obtain information about eigenvalues. This feature is particularly useful in an interactive design context.

86-930
Domains of Attraction for Multiple Limit Cycles of Coupled Van Der Pol Equations by Simple Cell Mapping
Jianxue Xu, R.S. Guttalu, C.S. Hsu
Xi'an Jiaotong University, The People's Republic of China
Intl. J. Nonlin. Mech., 20 (5/6), pp 507-517 (1985) 8 figs, 17 refs

KEY WORDS: Nonlinear theories, Van der Pol method

One of the most difficult tasks in nonlinear analysis is to determine globally various domains of attraction in the state space when there exist more than one asymptotically stable equilibrium states and/or periodic motions. The task is even more demanding if the order of the system is higher than two. In this paper two coupled van der Pol oscillators are considered which admit two asymptotically stable limit cycles. For systems of this kind it is shown how the method of cell-to-cell mapping can be used to determine the two four-dimensional domains of attraction of the two stable limit cycles in a very effective way. The final results are shown in the form of a series of graphs which are various two-dimensional sections of the four-dimensional state space.

86-931
The Analysis of the Square Array of Van Der Pol Oscillators using the Averaged Potential
M. Kuramitsu, F. Takase
Kyoto University, Kyoto, Japan
Intl. J. Nonlin. Mech., 20 (5/6), pp 395-406 (1985) 11 figs, 17 refs

KEY WORDS: Van der Pol method

An approach to finding stable oscillation in van der Pol oscillators with many degrees of freedom is described. A new concept of the averaged potential is summarized which is derived from the mixed potential. This method is successfully applied to the analysis of a square array of van der Pol oscillators coupled by inductors. It is shown that the triple and quadruple mode oscillations can be stably excited as well as simple and double mode oscillations.

MODELING TECHNIQUES

86-932
Modelling the Dynamics and Kinematics of Mechanical Systems with Multibond Graphs

M.J.L. Tiernego, A.M. Bos
Twente University of Technology, Enschede, The Netherlands
J. Franklin Inst., 319 (1/2), pp 37-50 (Jan/Feb 1985) 21 figs, 10 refs

KEY WORDS: Bond graph technique, Mathematical models

A method to model mechanical systems with multibond graphs is described. The method is based on the description of the vector velocity relation of a moving point in a rotating system. This relation is incorporated in a bond graph. It is explained how connected mechanical linkages must be handled. Two simple examples are presented.

86-933
Determination of Normal Modes from Identified Complex Modes
H.G. Natke, D. Rotert
Curt-Risch-Institut fur Dynamik, Schall- und Messtechnik der Universitat Hannover, Fed. Rep. Germany
Z. Flugwiss. Weltraumforsch., 9 (2), pp 82-88 (Mar/Apr 1985) 2 tables, 12 refs (in German)

KEY WORDS: System identification techniques, Normal modes, Damped modes

Cases occur in practice in which the measured eigenmodes of the damped elastomechanical system are available and normal modes are desired. This problem is solved by improving an existing computational model, using measured eigenquantities (incomplete and erroneous) in a sub-system formulation. This improved computational model is then used to compute the eigenquantities of the associated undamped system. Computational examples show the influence of errors.

PARAMETER IDENTIFICATION

86-934
Application of a Method for Identifying Incomplete System Matrices Using Vibration Test Data (Anwendung der Identifikation unvollständiger Systemmatrizen aus Schwingungstestdaten)
M. Link
Universität Gesamthochschule Kassel
Z. Flugwiss. Weltraumforsch., 9 (3), pp 178-187 (May/June 1985) 9 figs, 2 tables, 4 refs (in German)

KEY WORDS: Parameter identification technique, Mass coefficients, Stiffness coefficients, Damping coefficients, Experimental data

In a preceding paper a theory of incomplete system matrix identification was presented. With this theory it is possible to identify the incomplete physical mass, stiffness and damping matrix as well as the modal characteristics of a structure from incomplete dynamic excitation. The excitation is called incomplete if the number r of excited modes is smaller than the number p of measuring degrees of freedom. In the present paper, two applications are presented.

86-935
Theory of a Method for Identifying Incomplete System Matrices from Vibration Test Data (Theorie eines Verfahrens zur Identifikation unvollständiger strukturdynamischer Systemmatrizen aus Schwingungstestdaten)
M. Link
Universität Gesamthochschule Kassel
Z. Flugwiss. Weltraumforsch., 9 (2), pp 76-82 (Mar/Apr 1985) 5 refs (in German)

KEY WORDS: Parameter identification technique, Mass coefficients, Stiffness coefficients, Damping coefficients, Experimental data

A method is presented for the identification of the physical and modal mass, stiffness and damping matrices of a structure in the case of incomplete excitation.

86-936
Parameter Identification in Distributed Systems
H. Baruh, L. Meirovitch
Rutgers Univ., New Brunswick, NJ
J. Sound Vib., 101 (4), pp 551-564 (Aug 22, 1985) 2 figs, 3 tables, 15 refs

KEY WORDS: Parameter identification technique, Mass coefficients, Stiffness coefficients, Damping coefficients

A method for the identification of the parameters entering into the equations of motion of distributed systems is described. Because the

motion of distributed systems is described in terms of partial differential equations, these parameters are in general continuous functions of the spatial variables. For vibrating systems, these parameters ordinarily represent the mass, stiffness and damping distributions. These distributions are expanded in terms of finite series of known functions of the spatial variables multiplied by undetermined coefficients. A method for the identification of the eigensolution is also presented.

86-937
An Evaluation of a Class of Practical Optimization Techniques for Structural Dynamics Applications
S.F. Masri, S.D. Werner
University of Southern California, Los Angeles, CA
Earthquake Engrg. Struc. Dynam., 13 (5), pp 635-649 (Sept/Oct 1985) 7 figs, 16 refs

KEY WORDS: Parameter identification technique, Optimization

A class of practical optimization techniques for parameter identification of realistic structural dynamic systems is evaluated. The techniques involve quasi-Newton methods together with an efficient procedure for estimating complicated error functions. Extensive numerical and graphical results demonstrate the effects of various optimization algorithm parameters on the rate of convergence of the objective function, the parameter vector error norm and the gradient norm. Guidelines are presented as an aid for addressing several significant issues in the practical application of structural dynamics optimization procedures.

86-938
Identification of Unsteady Aerodynamics and Aeroelastic Integro-Differential Systems
N.K. Gupta, K.W. Iliff
NASA Hugh L. Dryden Flight Res. Ctr., Edwards, CA
Rept. No. H-1313, NASA-TM-86749, 32 pp (Aug 1985) N85-32851/6/GAR

KEY WORDS: Parameter identification technique

The problem of estimating integro-differential models based on test or simulation data is dealt with. The identification techniques proposed for estimating parameters in models described by differential equations need to be considerably extended to deal with the integral terms. Conditions under which the integral terms may be approximated by algebraic values are discussed. The integro-differential models discussed are related to indicial models proposed by aerodynamicists to describe unsteady flow.

DESIGN TECHNIQUES

86-939
Design Spectra for Degrading Systems
G.J. Al-Sulaimani, J.M. Roessett
Univ. of Petroleum and Minerals, Dhahran, Saudi Arabia
ASCE J. Struc. Engrg., 111 (12), pp 2611-2623 (Dec 1985) 5 figs, 1 table, 18 refs

KEY WORDS: Seismic response spectra, Seismic design, Reinforced concrete

The effect of stiffness or strength degradation, or both, under cyclic loading on the seismic response of single-degree-of-freedom inelastic systems with 5% initial damping is investigated. Rules are proposed to construct inelastic design spectra for these systems (typical or reinforced concrete construction) as a function of the desired *displacement* (or *ductility*) *ratio*. These rules complement those used at present based on the response of simple elasto-plastic systems without any degradation.

86-940
Generation of Floor Response Spectra Including Oscillator-Structure Interaction
T. Igusa, A. der Kiureghian
University of California, Berkeley, CA
Earthquake Engrg. Struc. Dynam., 13 (5), pp 661-676 (Sept/Oct 1985) 8 figs, 3 tables, 29 refs

KEY WORDS: Equipment-structure interaction, Seismic design, Floors, Response spectra

A method is presented for generating floor response spectra for aseismic design of equipment attached to primary structures. The method accurately accounts for tuning, interaction and non-classical damping, which are inherent characteristics of composite oscillator-structure systems. The method is accurate to the order of

perturbation and is computationally efficient, as it avoids time-history analysis and does not require numerical eigenvalue evaluation of the composite oscillator-structure system. The results of a parametric study demonstrate the accuracy of the method and illustrate several key features of floor response spectra.

GENERAL TOPICS

CONFERENCE PROCEEDINGS

86-941
Vibration-Emission by Textile Mills and the Design of Weaving Hall (Untersuchungen der von Webereien ausgehenden Schwingungs-emissionen und Hinweise zu Websaal-Bauplanungen)
H.G. Natke, R. Thiede, K. Elmer
Curt-Risch-Institut f. Dynamic, Schall-u. Messtechnik, U . Hannover, Fed Rep Germany
Published by TNW-Textil-Industrie Service, GmbH, Moltkestr. 19, 4400 Münster, Fed. Rep. Germany (1985) 100 pp, Price 50.00 DM plus handling (in German)

KEY WORDS: Vibration control, Industrial facilities, Textiles

Vibration in the vacinity of textile mills was investigated experimentally and theoretically. The investigation comprised the measurement of machinery vibrations and theoretical investigation of the transmission properties of foundations and of soils. A detailed evaluation of results and recommendations for the design of textile mills is included.

BBIBLIOGRAPHIES

86-942
Feasibility of Simplifying Coupled Lag-Flap-Torsional Models for Rotor Blade Stability in Forward Flight
G.R. Nilakantan, G.H. Gaonkar
Hindustan Aeronautics Ltd., Bangalore, India
Vertica, 9 (3), pp 241-256 (1985) 22 figs, 18 refs

KEY WORDS: Propeller blades, Helicopters, Torsional response

The feasibility of simplifying coupled lag-flap-torsional models is explored for the low-frequency stability of isolated hingeless rotor blades in forward flight. Under linear and quasilinear propulsive trim conditions, stability is investigated for four cases: a base-line model with elastic lag bending, flap bending and torsion degrees of freedom, the modified elastic lag-flap model that neglects only torsional dynamic effects, and the rigid blade models with and without quasi-steady approximation to torsion. The method of equivalent Lock number and drag coefficient is used for qualitative insights into dynamic inflow effects.

AUTHOR INDEX

CALENDAR

MAY

5-9 32nd Annual Technical Meeting of the Institute of Environmental Sciences [IES] Dallas/Ft. Worth Airport, TX (IES, 940 E. Northwest Highway, Mt. Prospect, IL 60056 -(312) 255-1561)

12-16 Acoustical Society of America, Spring Meeting [ASA] Cleveland, OH (ASA Hqs.)

JUNE

3-6 Symposium and Exhibit on Noise Control [Hungarian Optical, Acoustical, and Cinematographic Society; National Environmental Protection Authority of Hungary] Szeged, Hungary (Mrs. Ildiko Baba, OPAKFI, Anker koz 1, 1061 Budapest, Hungary)

8-12 Symposium on Dynamic Behavior of Composite Materials, Components and Structures [Society for Experimental Mechanics] New Orleans, LA (R.F. Gibson, Mech. Engrg. Dept., University of Idaho, Moscow, ID 83843 - (208) 885-7432)

24-26 Machinery Vibration Monitoring and Analysis Meeting [Vibration Institute] Las Vegas, NV (Dr. Ronald L. Eshleman, Director, The Vibration Institute, 101 W. 55th St., Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254)

JULY

20-24 International Computers in Engineering Conference and Exhibition [ASME] Chicago, IL (ASME)

21-23 INTER-NOISE 86 [Institute of Noise Control Engineering] Cambridge, MA (Professor Richard H. Lyon, Chairman, INTER-NOISE 86, INTER-NOISE 86 Secretariat, MIT Special Events Office, Room 7-111, Cambridge, MA 02139)

24-31 12th International Congress on Acoustics, Toronto, Canada (12th ICA Secretariat, P.O. Box 123, Station Q, Toronto, Ontario, Canada M4T 2L7)

SEPTEMBER

14-17 International Conference on Rotordynamics [IFToMM and Japan Society of Mechanical Engineers] Tokyo, Japan (Japan Society of Mechanical Engineers, Sanshin Hokusei Bldg., 4-9, Yoyogi 2-chome, Shibuyak-ku, Tokyo, Japan)

22-25 World Congress on Computational Mechanics [International Association of Computational Mechanics] Austin, Texas (WCCM/TICOM, The University of Texas at Austin, Austin, TX 78712)

29-30 VDI Vibrations Meeting [Society of German Engineers] Wurzburg, Fed. Rep. Germany (Society of German Engineers)

OCTOBER

5-8 Design Automation Conference [ASME] Columbus, OH (ASME)

5-8 Mechanisms Conference [ASME] Columbus, OH (ASME)

7-9 2nd International Symposium on Shipboard Acoustics ISSA '86 [Institute of Applied Physics TNO] The Hague, The Netherlands (J. Buiten, Institute of Applied Physics TNO, P.O. Box 155, 2600 AD Delft, The Netherlands, Telephone: xx31 15787053, Telex: 38091 tpddt nl)

14-16 57th Shock and Vibration Symposium [Shock and Vibration Information Center] New Orleans, LA (Dr. J. Gordan Showalter, Acting Director, SVIC, Naval Research Lab., Code 5804, Washington, D.C. 20375-5000 - (202) 767-2220)

19-23 Power Generation Conference [ASME] Portland, OR (ASME)

20-22 Lubrication Conference [ASME] Pittsburgh, PA (ASME)

NOVEMBER

3-6 14th Space Simulation Conference [IES, AIAA, ASTM, NASA] Baltimore, MD (Institute of Environmental Sciences, 940 E. Northwest Highway, Mt. Prospect, IL 60056 - (312) 255-1561)

30-5 American Society of Mechanical Engineers, Winter Annual Meeting [ASME] San Francisco, CA (ASME)

CALENDAR ACRONYM DEFINITIONS AND ADDRESSES OF SOCIETY HEADQUARTERS

AHS American Helicopter Society
1325 18 St. N.W.
Washington, D.C. 20036

AIAA American Institute of Aeronautics and Astronautics
1633 Broadway
New York, NY 10019

ASA Acoustical Society of America
335 E. 45th St.
New York, NY 10017

ASCE American Society of Civil Engineers
United Engineering Center
345 E. 47th St.
New York, NY 10017

ASLE American Society of Lubrication Engineers
838 Busse Highway
Park Ridge, IL 60068

ASME American Society of Mechanical Engineers
United Engineering Center
345 E. 47th St.
New York, NY 10017

ASTM American Society for Testing and Materials
1916 Race St.
Philadelphia, PA 19103

ICF International Congress on Fracture
Tohoku University
Sendai, Japan

IEEE Institute of Electrical and Electronics Engineers
United Engineering Center
345 E. 47th St.
New York, NY 10017

IES Institute of Environmental Sciences
940 E. Northwest Highway
Mt. Prospect, IL 60056

IMechE Institution of Mechanical Engineers
1 Birdcage Walk, Westminster
London SW1, UK

IFToMM International Federation for Theory of Machines and Mechanisms
U.S. Council for TMM
c/o Univ. Mass., Dept. ME
Amherst, MA 01002

INCE Institute of Noise Control Engineering
P.O. Box 3206, Arlington Branch
Poughkeepsie, NY 12603

ISA Instrument Society of America
67 Alexander Dr.
Research Triangle Pk., NC 27709

SAE Society of Automotive Engineers
400 Commonwealth Dr.
Warrendale, PA 15096

SEE Society of Environmental Engineers
Owles Hall, Buntingford, Hertz.
SG9 9PL, England

SESA Society for Experimental Mechanics (formerly Society for Experimental Stress Analysis)
14 Fairfield Dr.
Brookfield Center, CT 06805

SNAME Society of Naval Architects and Marine Engineers
74 Trinity Pl.
New York, NY 10006

SPE Society of Petroleum Engineers
6200 N. Central Expressway
Dallas, TX 75206

SVIC Shock and Vibration Information Center
Naval Research Laboratory
Code 5804
Washington, D.C. 20375-5000